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Reusable Building Systems

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By
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Class of 2011

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Reusable Building Systems

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Abstract

This project started out as an exploration of what it means to be permanent in architecture. I was dissatisfied with the current trend of architecture which is designed to last only a limited period of time. After exploring this for a bit, my conclusion was that any building which is going to last must be able to change alongside the society it supports. We already do this, we renovate and we rebuild, but it is not always efficient. Today, building materials can be reused to some extent, but they need to be remanufactured to make new pieces for new buildings.

What if, instead of the building lasting a "long time," the individual components were engineered to last as long as is practical. The Architect's "kit of parts" can become literal, with modules for every built component which can be assembled and disassembled to allow the building to change with its occupants, and perhaps even allow the occupants themselves to control the change, as opposed to hiring a construction company to make changes every time a wall is moved. Instead of gluing and nailing everything together as in light wood frame construction, we bolt everything together in heavy timber and steel.

As I set out to design this kit of parts, I quickly began to see that they needed a scalar module, an organizational rhythm, to ensure that the pieces would fit together whatever the variation and to provide a framework for further modules and elements to be added to the system in the futures, as advancements are made.

Nailing down the structural rhythm took time, and along the way I explored different massing organizations for site design and layouts for unit designs in order to incorporate these options into the organizational rhythm.

Finally, after many different parts and components and variations of connections, I arrived at a system which allows the occupant to alter their surroundings, to truly possess the space that they occupy. This system includes an organizational rhythm which can be adapted to the site or to specific desires for the building's use, as well as the steel structural system to impose that rhythm. The structural system, as well as all the other systems, are made up of differently sized modular parts which allow for simple on site construction as well as unforeseen changes and alterations to the system.

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01 Introduction

This project started out as an exploration of what it means to be permanent in architecture. It was about being immutable in an apparently transient environment. I was dissatisfied with the current trend of architecture which is not designed to last for very long. Having visited many archeological sites and being impressed at the extent to which comparably ancient structures survived I was left disillusioned at how "quickly" our buildings degrade. I was curious about long-lasting buildings, and how we might build them for modern uses. I began by considering the construction requirements for a long-lasting building. Great care would be needed in order to withstand extreme changes such as settling and degradation of materials; When looking too far into the future of the building, the very ground you build on becomes a viscous liquid, and building materials brittle.

I came to the conclusion that the societal issues that inform architecture change too rapidly to justify a long-lasting building. The immutability I wondered about was irrelevant. Instead, I found that in a quickly changing environment it is important that structures be able to match that change, that they be transient. If our architecture is nimble, it can meet changing demands more quickly.

The changes we make to the world are irreversible, so it is important that we be responsible with the resources we consume. Details in society are like a small scale model of that society; how Architecture it is built and maintained is a model for how society works, symbol for how we live and view the world. In our current system, it would appear that our society is disinterested in the future, perhaps by changing this small model we will advance the purpose of sustainability that much further.

We should nurture our ecosystem instead of supplanting it. We are dealing with limited energy and resources in the world, and if we had building systems which are designed with a sensitivity towards reuse we will have less wasted effort and materials. When buildings reach their end of life, the raw materials and systems they are made of can end up in landfills; even though we currently recycle many parts of a building, those parts still require processing to reuse.

What if, instead of the building lasting a "long time," as explored above, the individual components are engineered to last as long as is practical. The Architect's "kit of parts" can become literal, with modules for every built component which can be assembled and disassembled to allow the building to change with its occupants, and perhaps even allow the occupants themselves to control the change, as opposed to hiring a construction company to make changes every time a wall is moved.

Should the mark we make on the earth last? What about the resources and energy we expend to make that mark? Should that be transient? Should we be continuously renovating and rebuilding our image of society and the buildings that compose that society?

02 Problem Statement

Each year we expend a great deal of energy and materials to build structures that are constantly being torn down as our conception of "how things should be" changes. Perhaps this is an unchangeable quality of today's "replace, don't repair" mentality, or perhaps we should aim to change it. Shall we build quality buildings in a durable manner that can be expected to last 100 years or more? What would the future do with them? Would the program stay the same, and if not, how might the building respond to changing social conditions? What if society decided they were tired of the same old buildings, and tore them down anyway?

What if we went the opposite route, and built buildings that are meant to be taken down? Such "demountable" buildings could be made from reusable pieces, which can be reused again and again, and recycled when they wear out.

Why would we do that? Because we can not be pretentious enough to believe that we can predict what the future will want from our buildings, and we should not be so irresponsible as to allow the energy exerted building things today be lost tomorrow. We should be building in a manner which allows for reuse, without losing the energy and material that went into creating the building. This is not recycling, when you recycle you have to process the material, either melt the plastic or cut the wood up into smaller bits to laminate back together.

This is about designing building systems which could be directly reused, without critically changing or remolding them. This is about designing systems which will last or will be easily replaced when they wear down or new technology outdates them.

As a construct, a building has a limited lifespan. Our society changes, and with it the needs that our buildings fulfill change. We cannot know what future architects will be asked for, but we do know that there are limited materials in the world; while energy is constant, as a universal law, we continually disperse it, making it very difficult to gather back up. We can avoid that by building in a demountable, reusable, deployable manner.

The current trend of using shipping containers as a novel building material is an ideal example of reuse. What about the next generation? How will they reuse the things we build today? Can we build in a manner that allows the next architect the opportunity to re-imagine without rebuilding? I think that we should.

The current attitude of value engineering and mass development is irresponsible. While building things cheaply gets the job done today, those materials and the energy that went into them are lost to future architects. Flimsily built buildings may last the 40 or so years that we want out of them, but after that they are in such poor shape that they need to be severely renovated or demolished.

We should continue to endeavor to build in a manner which is not only sustainable, being responsible to the local and global environment, but which also acknowledges the end-of-life conditions our buildings will inevitably meet.

I propose to design sets of architectonics, building systems, or modules which can be reused, recycled or "down cycled" after the building's or building system's end-of-life.

Since I propose that this system will be used to transform building types as they reach their end of life, I will propose two separate sites, each with their own implications on the building. By designing each building with the same systems, I show the versatility of the design.

The program will be a residential complex; on one site the massing will be informed by higher local density and proximity to mass transit, while the other site suggests dispersed, lower density single family homes.

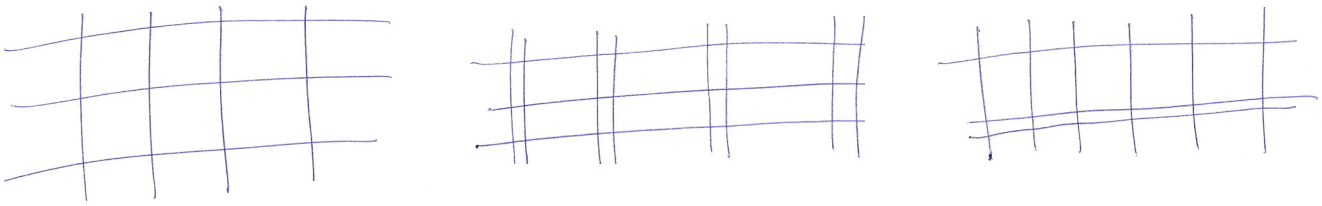
03 Architectural Intentions

Program

The site will be a dense residential block in a commercial, residential and office mixed infill developing area near mass transit. The site is slated for development to replace a disused commercial and industrial area. Extensive urban renewal and infill is planned to encompass the site. The site is located in Prince William County, Virginia.

Structural system

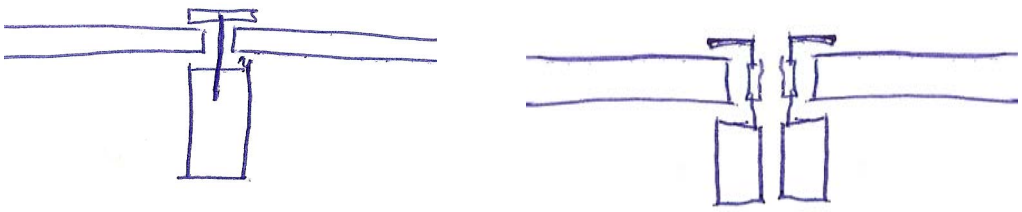
Structure defines the form and nature of a building design. It is important that the scale and rhythm of the structural system be informed by the scale and use of the programmatic elements. In the case of this thesis, the program will be a residential apartment so the spans will not be great, and the rhythm will allow apartments to span any number of bays to accommodate differences in apartment size and function.



Development of an envelope system

The envelop system should be modular to allow each apartment to manage (clean and maintain as well as renovate) their respective facades. I envision a unitized facade panel system with a variety of panels to suit the various needs for a facade such as ventilation, shading, transparency as well as opacity. This system should be a series of modules which address standard corner and edge conditions; each attach to the structure for primary loading and each other to create a secondary self-support.

I mention a unitized mullion system because it incorporates the mullion into the panels to allow each panel to remain integral while it is being transported and allows the facade to be constructed (and in my case, deconstructed) panel by panel, instead of the much more complicated monolithic mullion system.



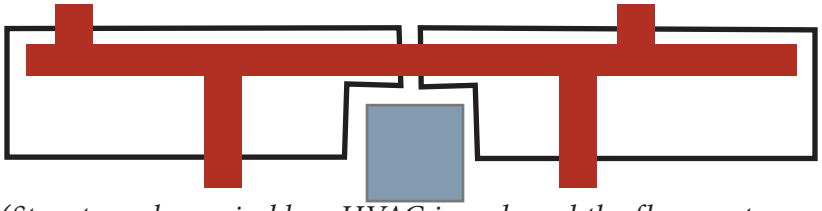
Monolithic Mullion System vs Unitized Panel System

Finish Systems

There already exist many products in the market for sustainable and responsible finish materials. Bamboo flooring is a good example of one such product, and wool can also be used for carpeted areas. This system is analogous to the envelop system, creating the interior shells of the individual spaces. Each different system (walls, floors, plumbing walls, parti walls, etc) will be composed of a panelized system which will detail individual panels and how they would fit together and connect to other systems.

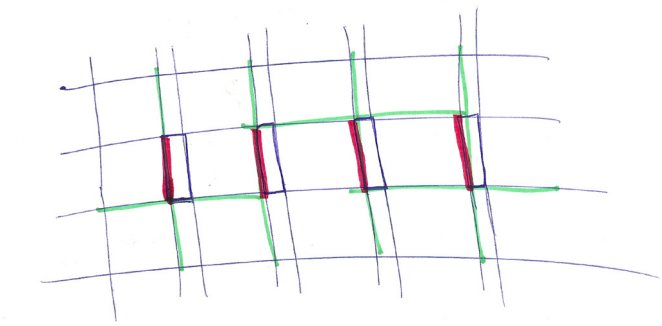
Technical Systems

This is not really a module by itself, but rather is inserted into another system, such a raised floor assembly or a suspended ceiling assembly or precast slab, so that it is universally distributed and can be "tapped into" in different construction configurations. Perhaps the floor system becomes a complete system with HVAC installed above (or below) the structural level of the floor and taps down to registers in ceilings below where needed.



(Structure shown in blue, HVAC in red, and the floor system in white)

Another solution to the problem of providing MEP services to all areas of the building would be to incorporate those services into the wall system, so that some walls carry services vertically throughout the building and other walls can provide connections to those vertical risers for other areas of the apartments. If this solution is used, perhaps a specific place in the structural rhythm can be given over to the vertical riser so that it is continuous throughout apartments and expansion.



Red represents vertical riser and green horizontal services in walls. Blue is the structural building rhythm.

04 Precedents

Boucher Grygier House

Leger Wanaselja Architects. East Bay, California. Feb 2010

This house uses refrigerated shipping containers as massing for smaller program areas, then spans between them to create open program such as the living room. The architects cut openings in the containers for windows and interconnected open spaces inside. They only have to reinforce the container where they have cut through it, and the containers themselves are already insulated well above required codes. Simple passive solar principles are employed in the system, such as deep eaves to minimize solar gain.

This is a 1350 square foot house with three bedrooms. It is luxuriously finished with fine yet sustainable bamboo wood flooring and wool carpeting. The house uses only green-seal low-VOC paints and water-based urethane finishes. Collecting rainwater on the roof helps to reduce the footprint as well. Blown-in cellulose insulation is used in areas not inside the already-insulated shipping containers.

Two full containers are stacked on the left side of the building, and one container is cut in half to stack on the right side. Beams span the space in between to create a luxurious double height living space.

The double height living space is finished with wool carpeting. One can see one of the beams which spans between the containers, supporting the walkway between bedrooms above.

Inside the left-side (from picture on previous page) container the dining area and kitchen are quite small, but with minimal clutter the space is roomy enough for its purposes, and with broad openings to the double height space the dining area does not feel claustrophobic.

Openings cut into the containers after placement on site are reinforced internally, and insulation added to the roof. Other than that the containers need only be clad in finish materials.

The final container being lowered into place.

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Ellia Jones Residence

Leger Wanaselja Architects, 2005

Another excellent house by Leger Wanaselja Architecture reuses an existing structure but overhauling it from a rather shabby energy-consuming and boring house into an efficient and sustainable residence. They were fortunate enough to be able to reuse 6000 board-feet from fallen trees on site, which contributes to the finishes on the interior as well as parts of the structure for the building, and furnishings.

Rainwater is collected into a 10,000 gallon tank and the house uses solar hot water heating. By having a high thermal mass and replacing the aging windows with new low-e double paned ones, the house is better able to passively heat and cool itself.

In addition to being a sustainable building, the residents also grow food on the property and have facilities for canning and storing, which contributes to the local ecosystem in another positive way.

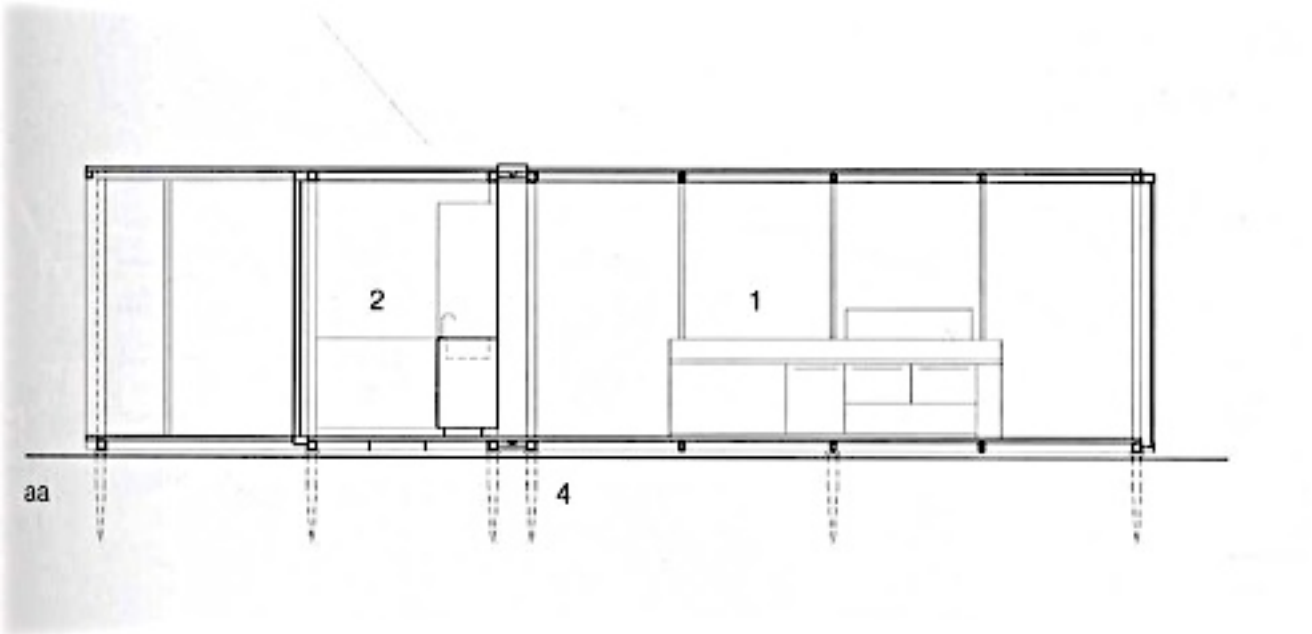
A new roof with more efficient insulation does a lot towards making the building more sustainable. Wood siding and supports are reclaimed wood from trees which fell on site.

Again, much of the wood used in the renovation is reclaimed, the architects found many creative ways to use the wood throughout the design. In other places they use bamboo flooring.

Mobile Exhibition Pavilion

Jürke Architects, Munich, 2009

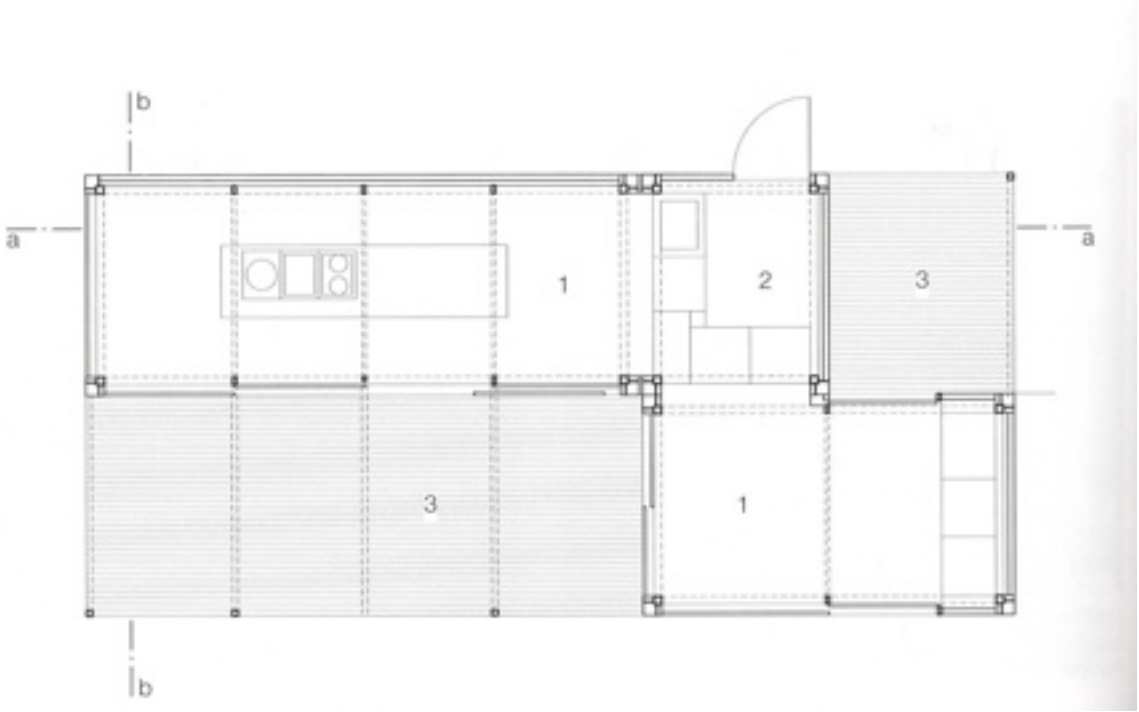
This portable showroom is particularly salient to my thesis because of the mutual requirement of de-construct-ability. It has been designed by Rainer Huxel and Jürke Architekten. The structure is comprised of a HSS steel frame with suspended curtain wall panels. The panels are prefabricated so that on-site construction can be completed in one day without the need for high-precision. The interior climate of two showrooms is regulated by a central climate control module, which also provides electricity, water and drainage. The modules can be deconstructed for transport in 45' containers. Interestingly, the highest stress on the panels occurs during crane placement; for this reason there is removable cross-bracing used only during shipment which locks into architectural reveals around the edges of the panels.



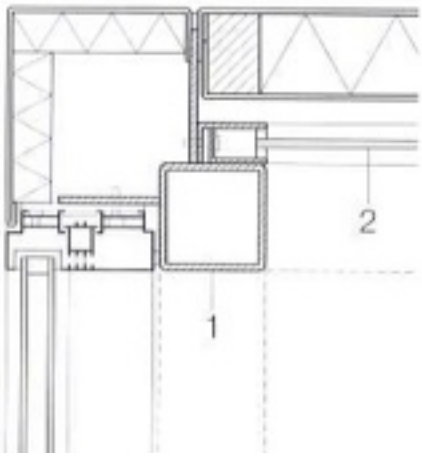
The steel frame rests on a precisely placed screw foundation which can be removed to leave the site relatively un-damaged.

Here one can see the diagonal bracing added to the glass panel system during transport and installation.

Below: the two exhibition spaces, labeled 1, with the mechanical module in between, labeled 2.

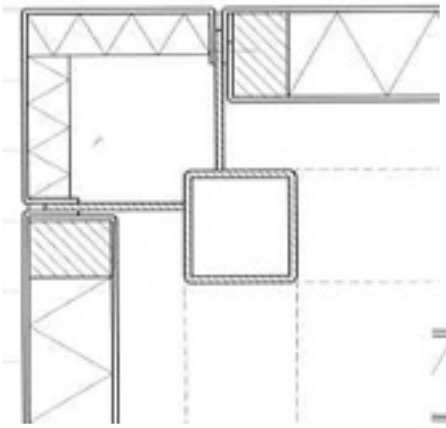


Left: A construction test underway in the assembly factory. The deck, mechanical module, and one showroom module is shown fully constructed as the second showroom module is lowered into place by crane.

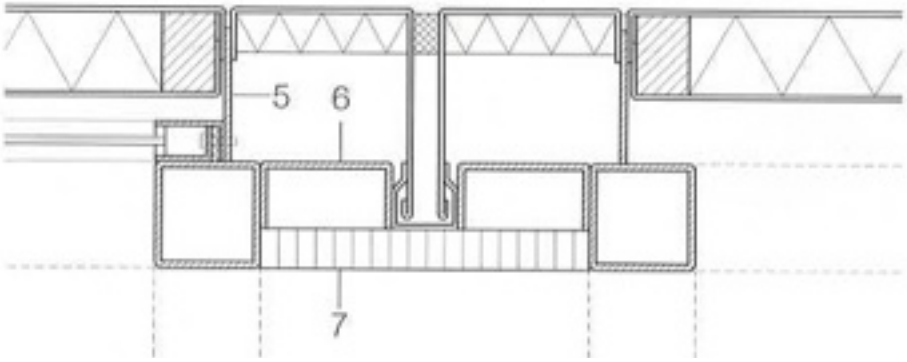


At left are two planar details through the HSS (1) at the corner, one with a window (top) and without (bottom). The top detail also shows an opaque glass panel (2) which is used in some interior areas as a finish.

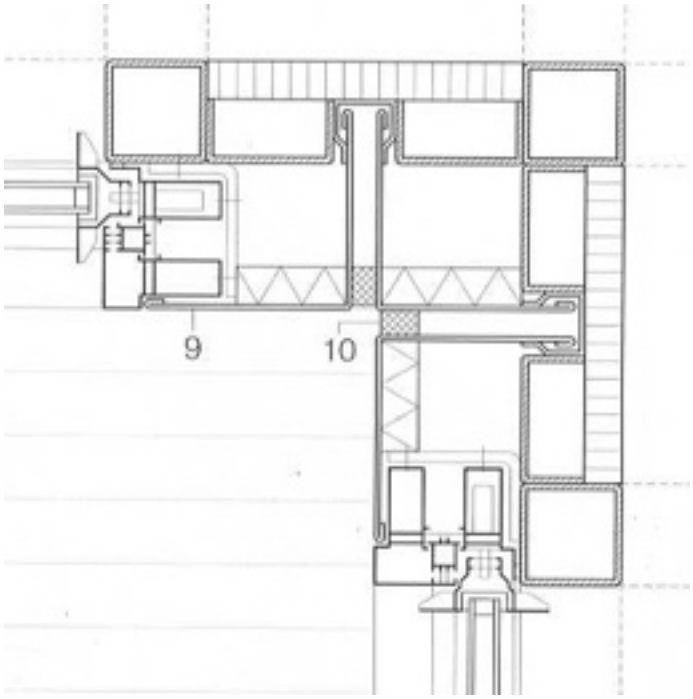
Below is the planar detail of where two corners abut, without an interior partition. Labeled 5 in the image is a steel plate welded to the HSS, to support the insulation panels. Labeled 6 is a steel channel to reinforce the corner. 7 is wood veneer for an interior finish.



Detail of where three corners abut, this time forming the knuckle of the L-shaped building. Labeled 9 is sheet steel



rolled to form the exterior of the envelope with (10) EPDM tube sealant rubber seals.



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Chantepie Housing

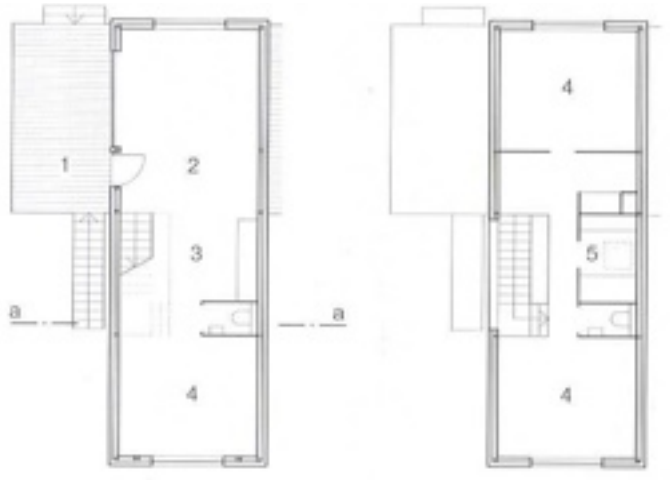
Chantepie, France. Architect Eric Lenoir.

In this development Lenoir has created a serialized system of modules which divided the construction of the house into three parts: the frame, the roof, and the exterior metal envelope. This way, the houses can be built very quickly as each uses the same basic building blocks and building process. The roof components are constructed on the on site and then lifted into place. The houses are based on a 60cm grid, which is presented as three different house types based on column span: 360, 420, and 480cm.

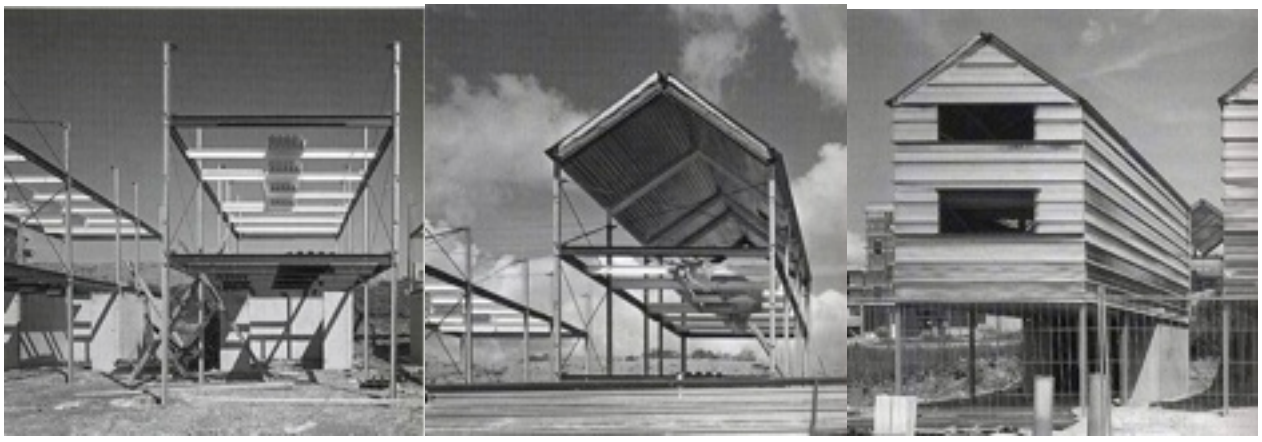
The insulated portion of the houses is lifted off the ground to allow for parking under the structure. Labeled on the plan, (1) a deck which enters onto (2) the main living space with a (3) kitchen and (4)

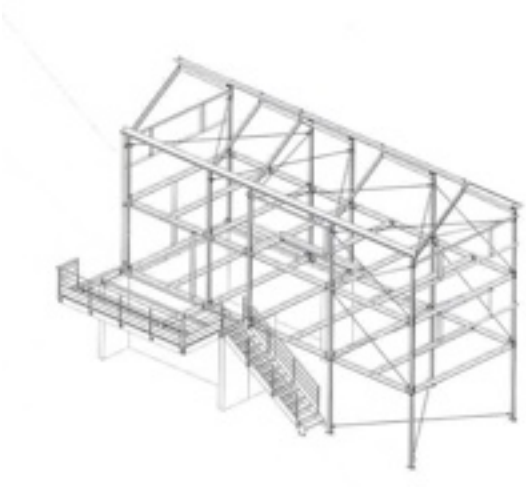
dining. Upstairs, (4) bedrooms taking advantage of light at the ends of the mass and (5) bathroom and service in the middle.

Below: the three stages of construction. First the steel frame is installed. The prefabricated roofing panels, with integrated structure, are installed. Then the exterior metal sheathing panels are installed.

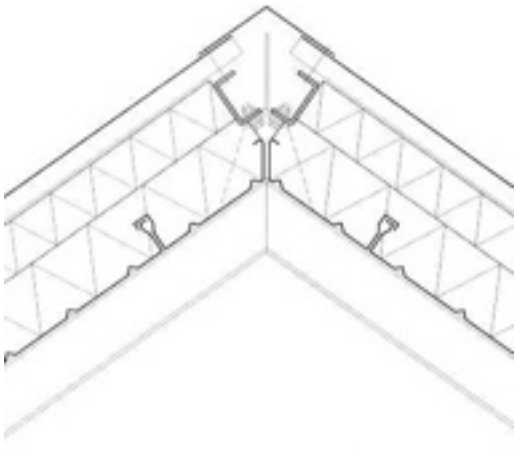


Here you see the complete frame system with cross bracing shown in two planes (plan and one section). Steel frame with rigid connections at the intersection with the second floor and at the ground is sufficient to resist lateral loads.



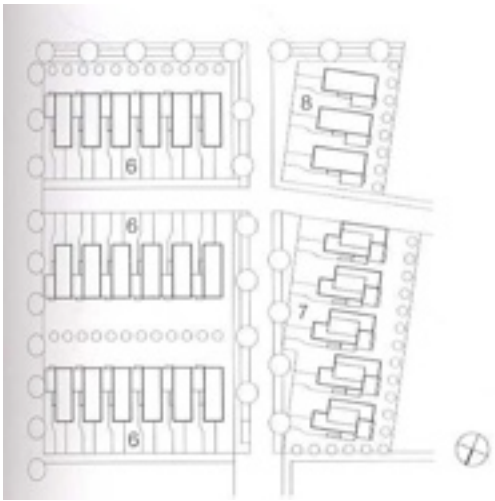


Here is the ridge detail, showing bolted channels which are connected to steel I-beams [sic] (out-of-plane). On exterior is 39mm corrugated sheet metal, painted black, followed by 100mm of glass wool insulation and then 130mm of rock wool insulation. More standing seam sheet steel on the inside is attached to the I-beams [sic] (out-of-plane).

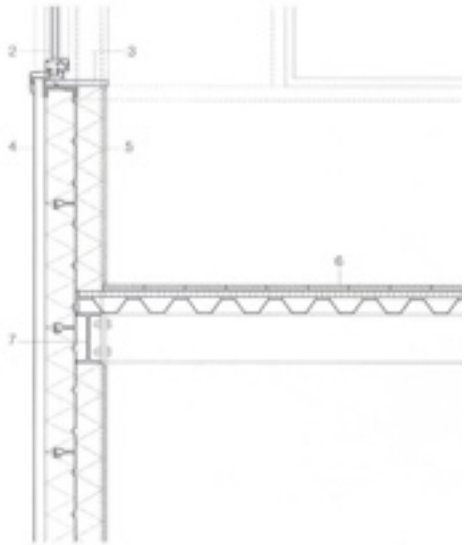


The site plan is rather squarely divided into plots for the three different house types, labeled at left 6 7 and 8. It is interesting to note that while individual units in type 6 do not appear to be oriented with particular concern for solar orientation, the group of rowhouses as a whole is east/west oriented; The 7 & 8 type units are east/west oriented as individual units.

Here you see the wall detail at the intersection with the second floor. Steel I-beams [sic] support



corrugated sheet metal, which supports the span between beams. Above the sheet metal is a layer of acoustic fleece and OSB panels followed by the parquet finish. The wall is, again, corrugated metal on the exterior, with 110mm of rock wool insulation and, again, another layer of corrugated standing seam sheet metal with more (100mm) glass wool insulation on the inside, finished with gypsum board.



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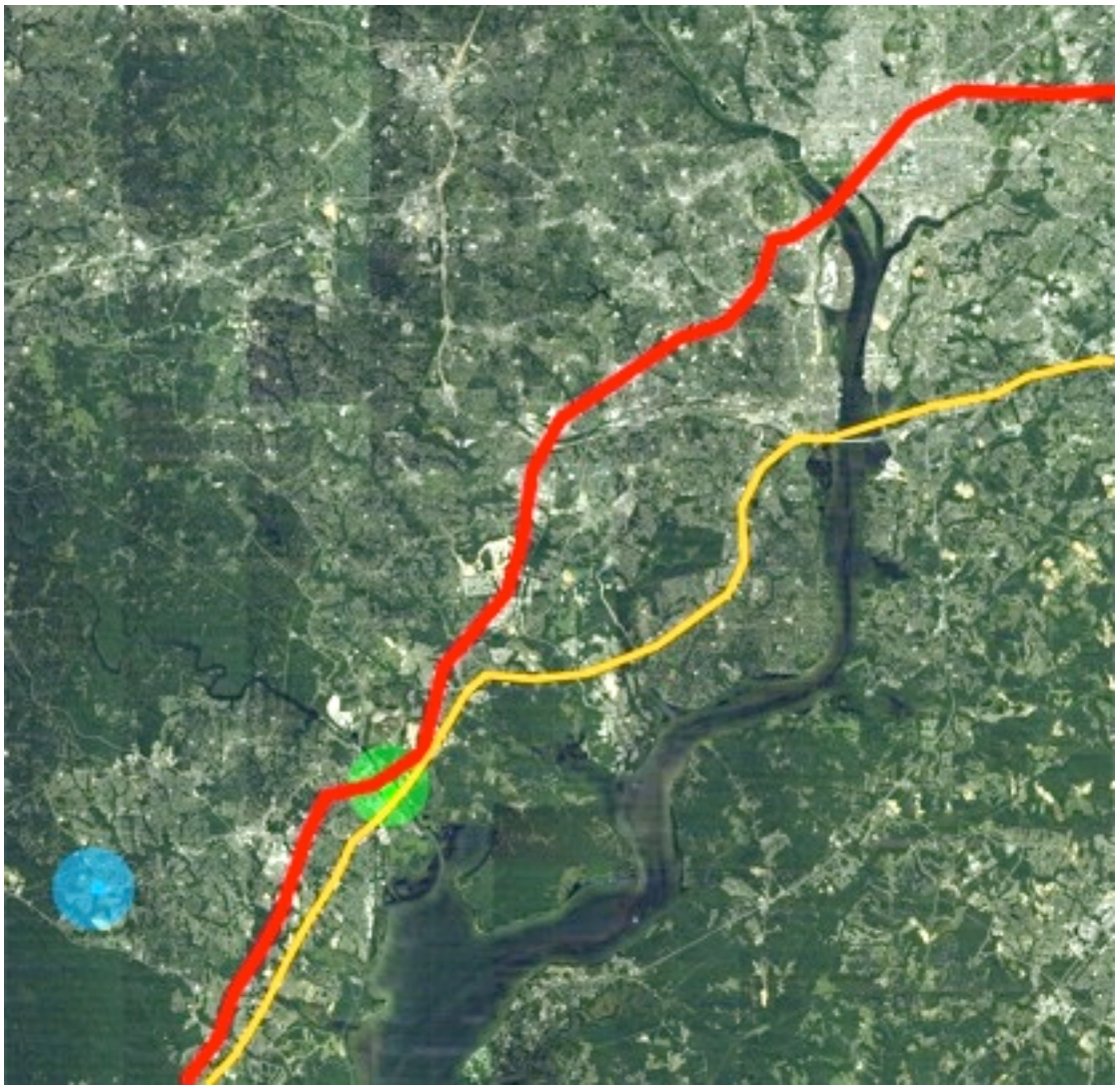
05 Siting

In order to show the different typologies that this system is able to produce, I have proposed two sites. This allows for both a medium density apartment building and a number of single family residences to be articulated.

The satellite image below shows both sites in relation to Washington DC (top right) and the I-95/Route 1 corridor. Site A, highlighted in blue, is situated away from the transportation corridor in suburban Dumfries, Virginia. Site B, highlighted in green, is situated closer to the I-95 & Route 1 transportation corridor, in a planned redevelopment area in Woodbridge, Virginia.



Satellite image from Google maps with Route 1 in yellow and Interstate 95 highlighted in red. Potential sites marked in blue and green.

The suburban site, Site A, is surrounded by developments and wooded land. The focus on this site will be single family residences on individual plots of land. A community-centric overall plan with inwardly-focused 4-5 bedroom houses will be developed on this site.

Currently, The medium density site, Site B, is a part of an undersused area planned for redevelopment. The commercial center nearby is all but abandoned, and because the site is situated in a prime location along the corridor it is ideal for redevelopment. The county's plan shows a medium density urban center with apartments, retail and new office buildings.

06 Site A "Single Family"

Site Zoning

Currently the site is zoned as agricultural, but the county has published a proposal to redevelop this unused green space into a housing development and possibly an elementary school on the site, so I believe it is reasonable to propose a sustainable community here.

The development plan by the county rezones the site as R-4, with a density of 4 plots per acre allowed by the code. The portion of the site that the houses are situated on is around 15 acres, allowing a maximum of 60 houses, with siting conditions and roads taken into account, about 50 houses is a reasonable number.

Set back requirements for R-4 zoning are 30 feet from the front property line, 25 feet from the rear, and 10 feet from the sides. A corner lot may use a 20 foot setback from the lesser front. The setback is 25 feet from any property line shared with a commercially zoned property, and 35 feet from any property line shared with a property zoned industrial.

The code also specifies a maximum building height of 35 feet, with a minimum lot size of 10,000 square feet (four lots per acre). It also requires that a lot have at least 70 feet of street frontage, and that a building cover no more than 40% of its lot.

Site Use

There is a proposal for an elementary school and a small community on the site, as shown in the county's drawing below. In this drawing there are 50 plots shown and a chunk of the site reserved for an elementary school.

Site Adjacencies

The site is prototypical for a suburban community. It will be important, aside from the main implications of my thesis, to create a separate community that at once is inwardly focused in a manner to create a community while integrated with the existing fabric of the larger neighborhood.

Immediately adjacent to the site is a shopping center and just up Spriggs road is a high school and a middle school. There is a proposal to add an elementary school to the site itself.

Program

The site is large enough to accomodate 28 residences. I would propose 18 four-bedroom houses, and 10 three bedroom.

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Site Layout

Site Size: 473,000 sf (11 acres)

Minimum plot size: 10,000 sf

Street Frontage: 70ft

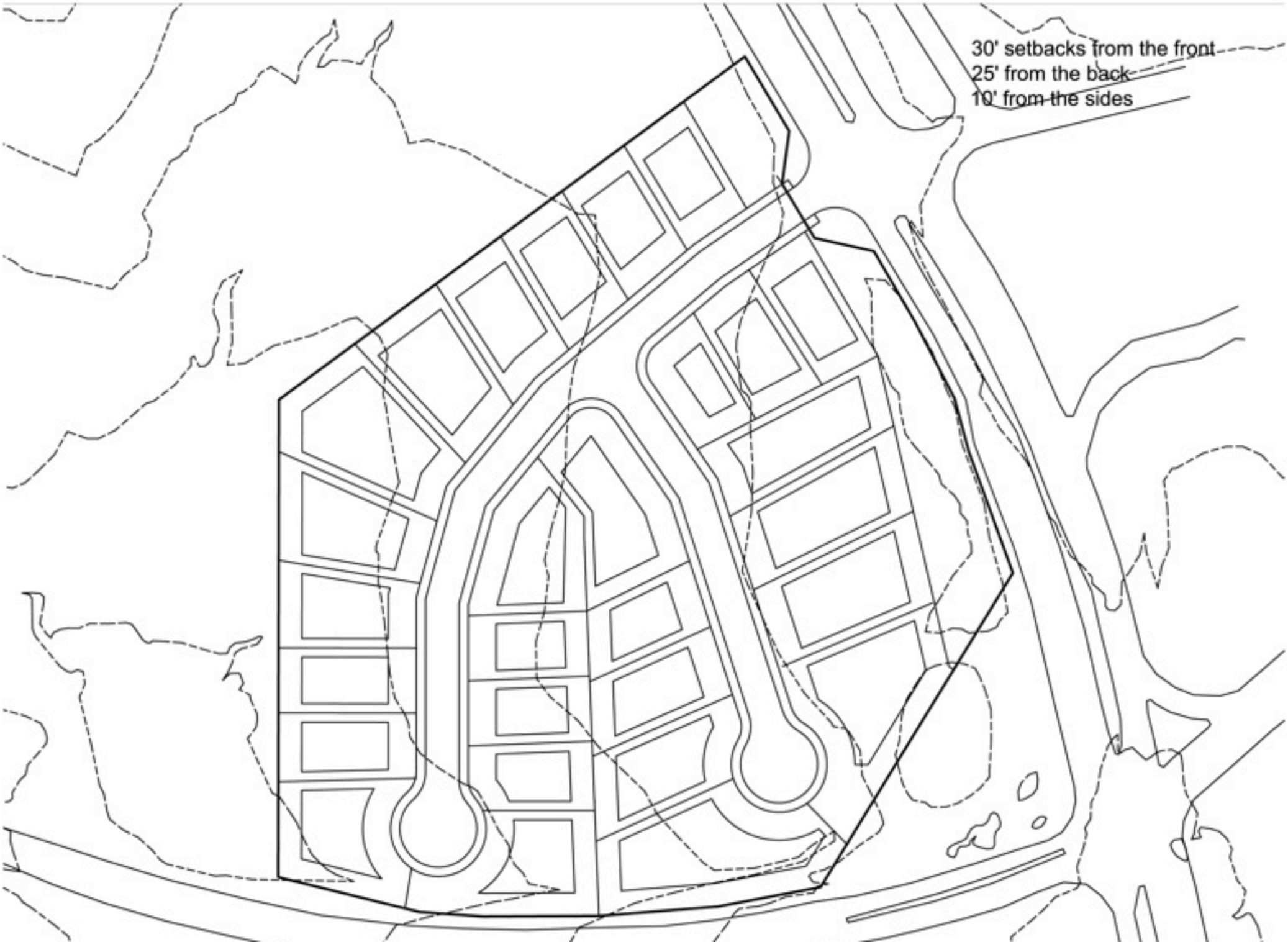
Max Footprint: 40%

Front Setback: 30’

Side Setback: 25’

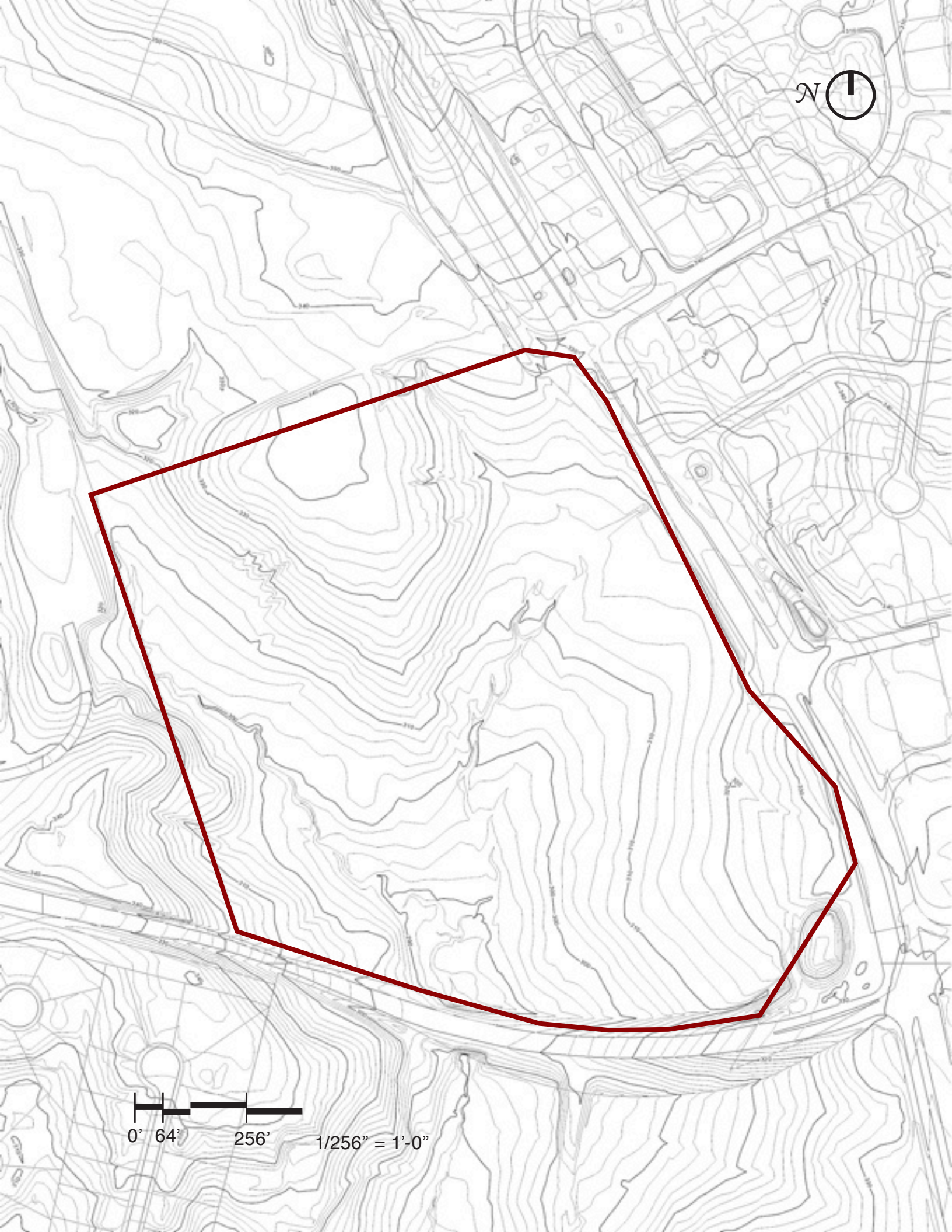
Rear Setback: 10’

Total of 28 plots.


30' setbacks from the front
25' from the back
10' from the sides

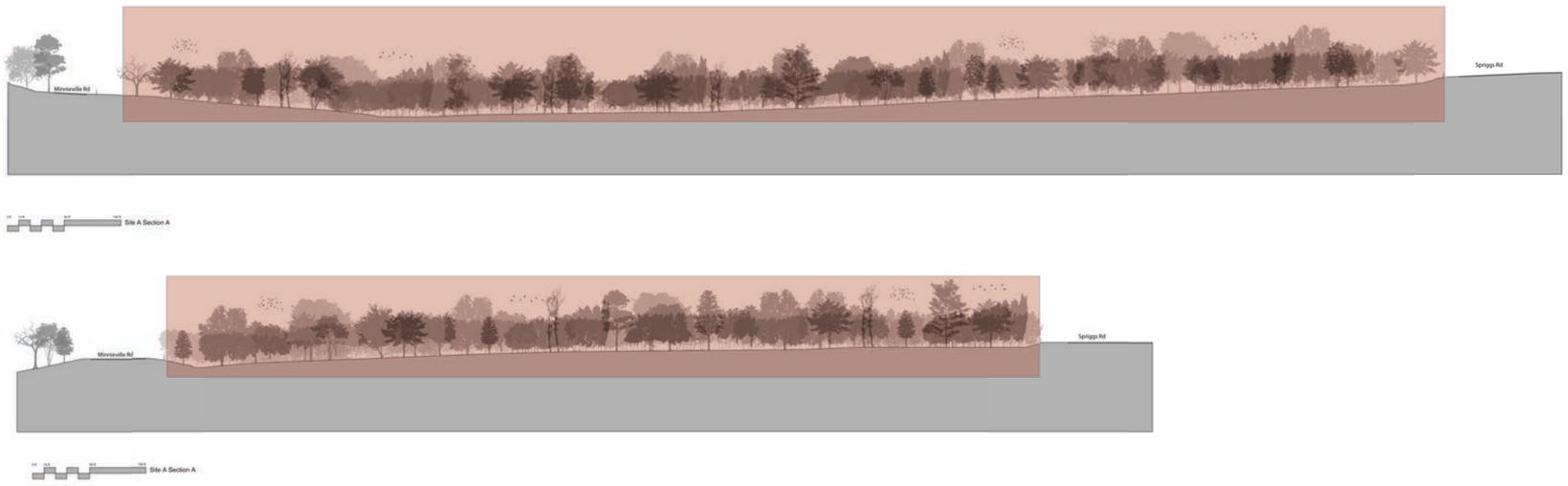
Site Topography

Whole area zoned for development shown outlined, actual community area smaller (tbd).


N
0’
64’
256’
1/256” = 1’-0”

Site Sections

Site area highlighted.



The section of the existing conditions on the site, specific property outlined in red.

Client

Residents are established families with a few children and two adults in the first few years of home ownership, but this blossoms into a mixture of adults and young adults as the youngest generation goes through school and university or the job market. They have shifting schedules and occasionally meet for dinner or to hang out, but largely put up the impression that they lead separate lives; they are somewhat codependent as a group. Eventually parts of the younger generation split off and form their own households.

Adjacencies

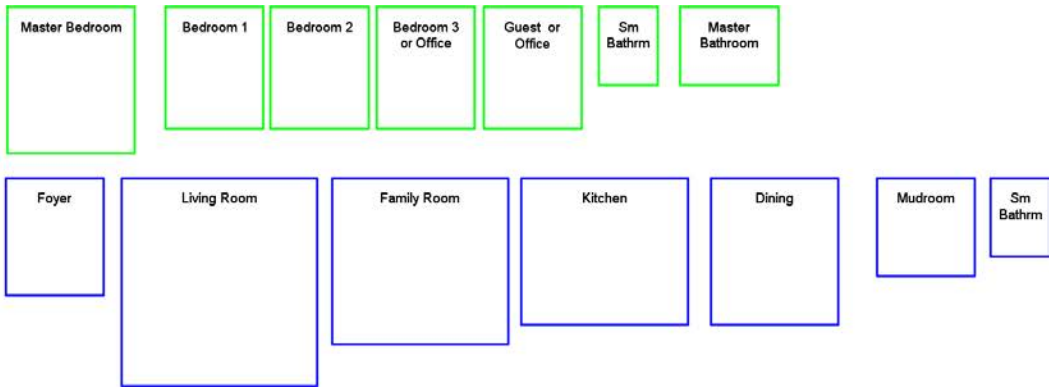
The house is a part of a fabric in the community and it is important not to deny that in the articulation of the siting. The possibility of presenting a community instead of a group of houses provides for the creation of a real social network. In order to stimulate the growth of such network, each home must have a level of privacy and intimacy in its setting and orientation of program on the site, while allowing for

Program Areas

Master Bedroom	15x13	195 sqft	Den / Family Room	18x17	295 sqft
Bedroom 1	12x11	132 sqft	Kitchen	17x15	255 sqft
Bedroom 2	12x11	132 sqft	Dining	15x13	195 sqft
Bedroom 3 / office	12x11	132 sqft	Mudroom		100 sqft
Bedroom 4 / guest	12x11	132 sqft	Small Bathroom	6x8	50 sqft
Foyer		120 sqft	Small Bathroom	6x8	50 sqft
Living Room	20x21	420 sqft	Master Bathroom	10x8	80 sqft

Net Total . . . . . 2,288 sqft

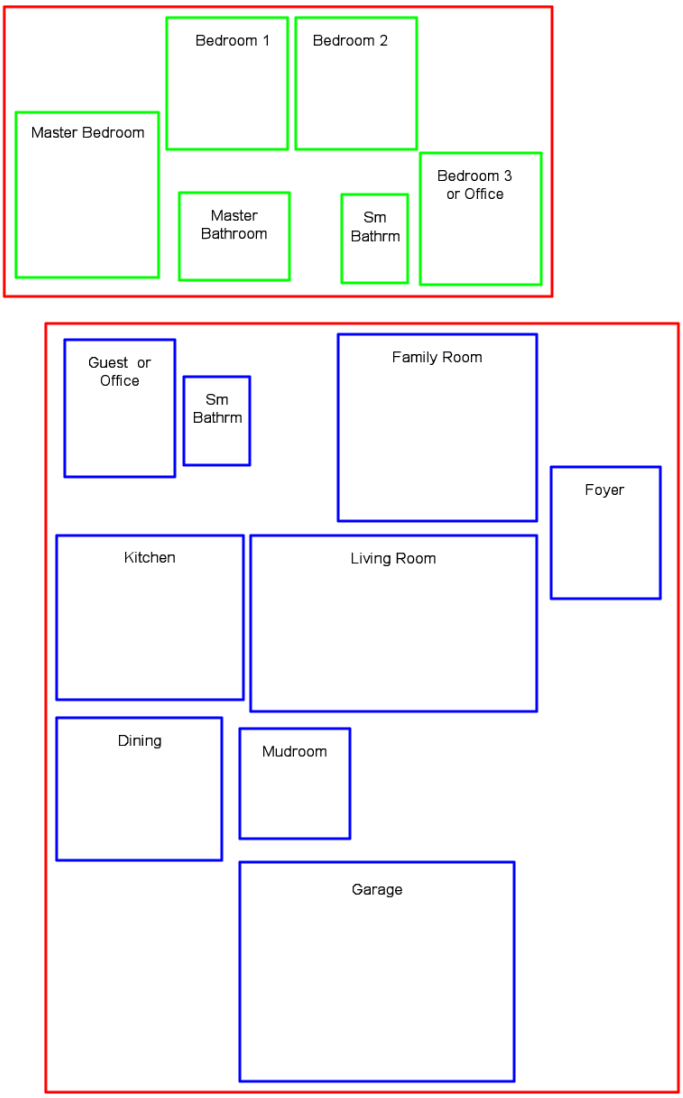
Gross Total . . . . . 3,000 sqft



non intimidating interstitial spaces between the public sidewalk and the more intimate setting of the living room.

Interrelations

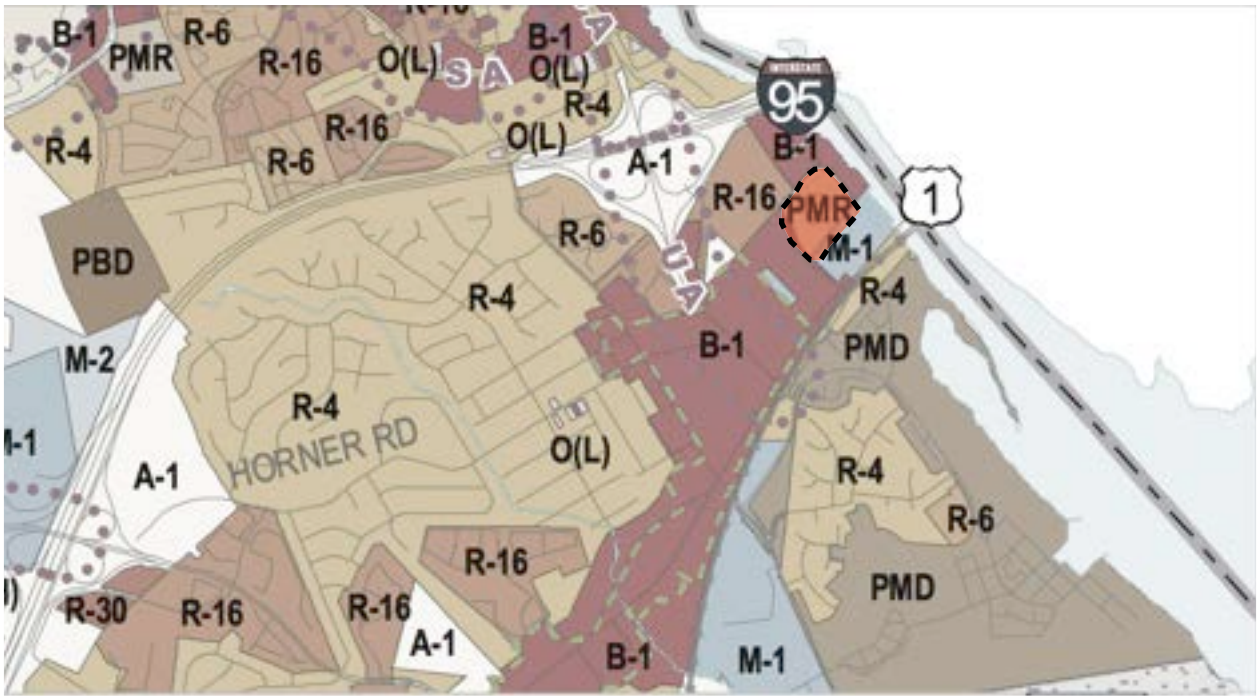
Here the house is divided into somewhat private areas and more public gathering spaces, with a clear but permeable boundary between the two. Gathering spaces such as the kitchen, dining room, den, foyer, and living room are generally open with minimal separation to provide visual spatial interest and minor sound muffling. Exterior spaces should provide visual interest connecting interior spaces to one another.



07 Site B: "Mixed-Use Mid-rise"

Site Zoning

In this case the site is adjacent to many different layers of transportation, while being large enough to be buffered from them. It is within walking distance to the Virginia Rail Express line as well as bus services, Interstate 95 and Route 1.



The site itself is zoned PMR (Planned Mixed Residential). The area around this site is partially zoned R-16, 16 dwellings per acre, and B-1 General Business. There is a small M-1 (Heavy Industrial), which is not shown in the development plan so I presume that it is being removed entirely. The proposal by the county for redevelopment shows the whole site as being either mixed residential or business with retail on the first floor.

For a Townhouse unit type, the maximum building height is 35 feet, with a minimum lot width of 20 feet. Setback on the front side is 10 feet with off street parking, or 20 feet with a garage. From the side of end units 10 feet is required, and 20 feet for the rear or a public right of way. For unroofed decks,

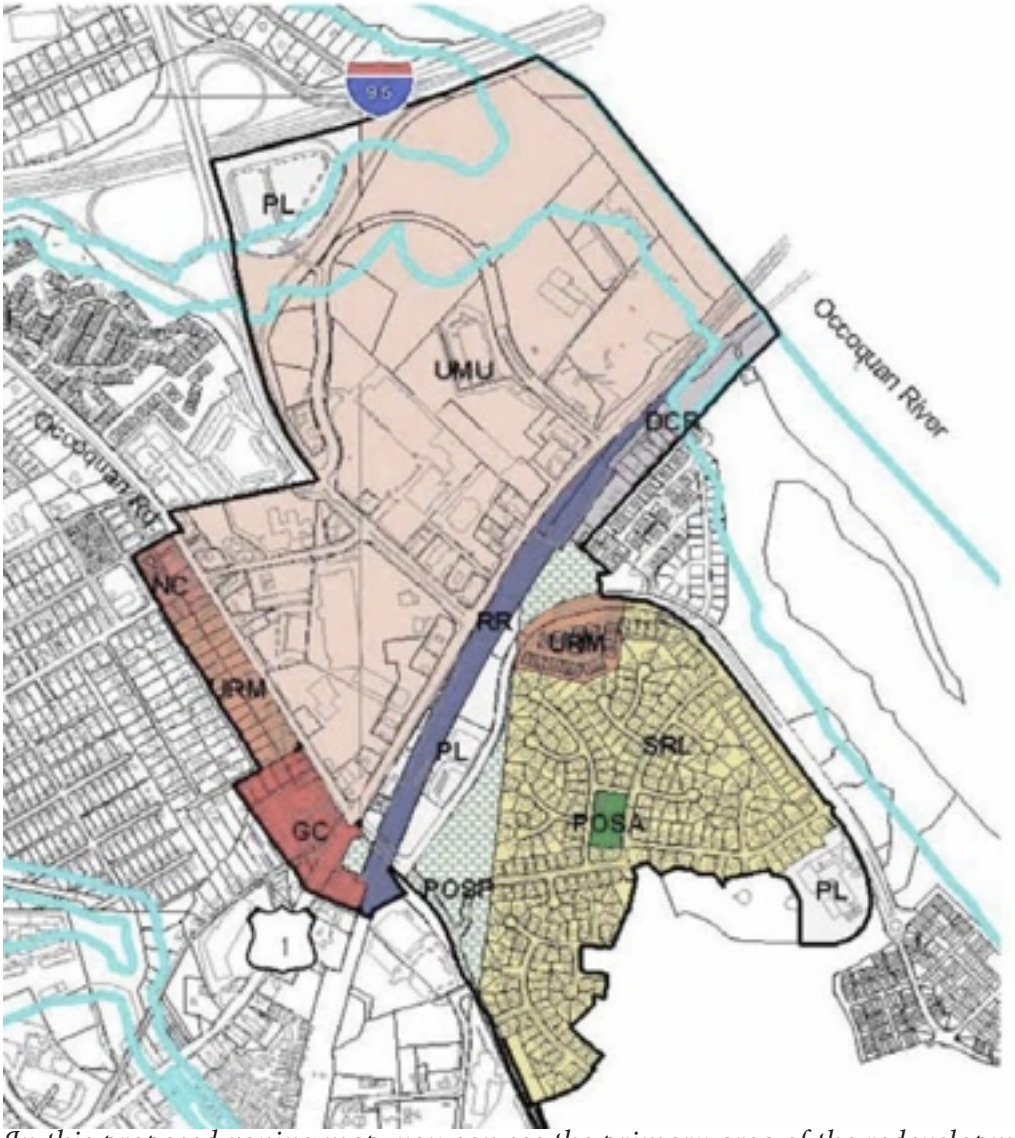
stoops, landings and the like there are setbacks of 5 or 15 feet from the front, 10 feet from the side, and 8 feet from the rear. Setback must vary by two feet between units, except two adjacent units may share a setback. Façade detailing must be varied between units. The minimum building footprint is 720 square feet and 30% open space on the site.

For a multifamily building the minimum lot area per unit is 2000 square feet for a single story building, or 1725 square feet for a two story building and 1450 sqft for three and greater stories. The maximum lot coverage is 75%. Maximum building height is 50 feet. Required setbacks are 35 feet from the front, 25 feet from the rear and 20 feet from the side. Setback from structured parking is 20 feet, or 12 feet from a parking lot. There is a different rear setback from balconies or decks which is 20 feet.

Site Use

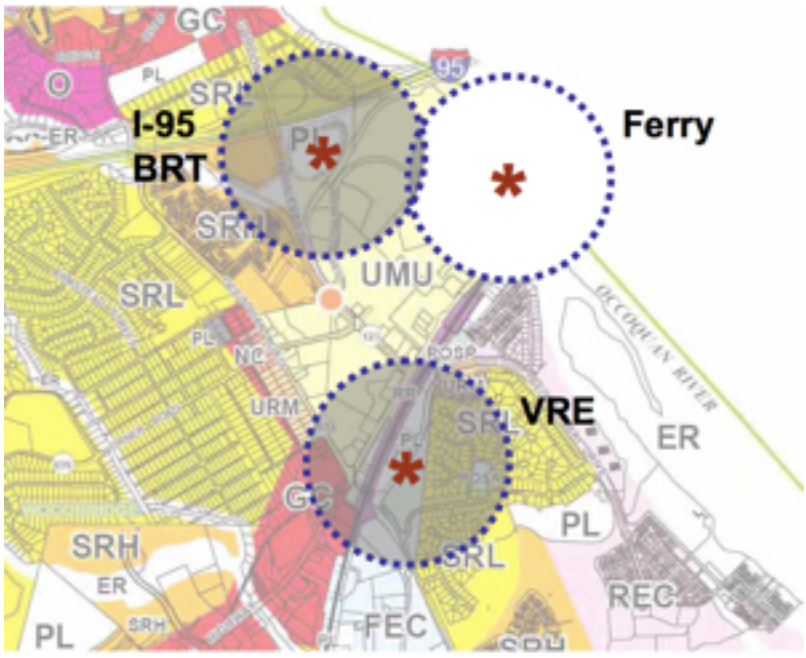
The site is a disused area of land ideally located along interstate 95 and Route 1. Some diagrams relating to proposed site massing and zoning are shown below, from a county-organized charrette on the proposal.

I will focus on the overall layout of an apartment & townhouse building with commercial below, to fit within the proposed master plan from the county.



In this proposed zoning map, you can see the primary area of the redevelopment labeled "UMU", where the county plans to establish an urban center with high-end shopping,housing and offices.

A proposal for the massing of two stages of the redevelopment, the main area I am focusing on on the left, and an area just to the south around the MBTA Line.



This diagram shows the proximity to some auxiliary mass transit options: a proposed ferry, the BRT bus to washington, and the Virginia Rail Express which connects to the Washington Metro. Quarter mile walking distances are outlined with the purple dashed circles.

Site Layout

Program:

Townhouses: 16

One Bedroom: 16

Two Bedroom: 16

Net Square Footage: 196,800 sf

Site footprint: 152,000 sf

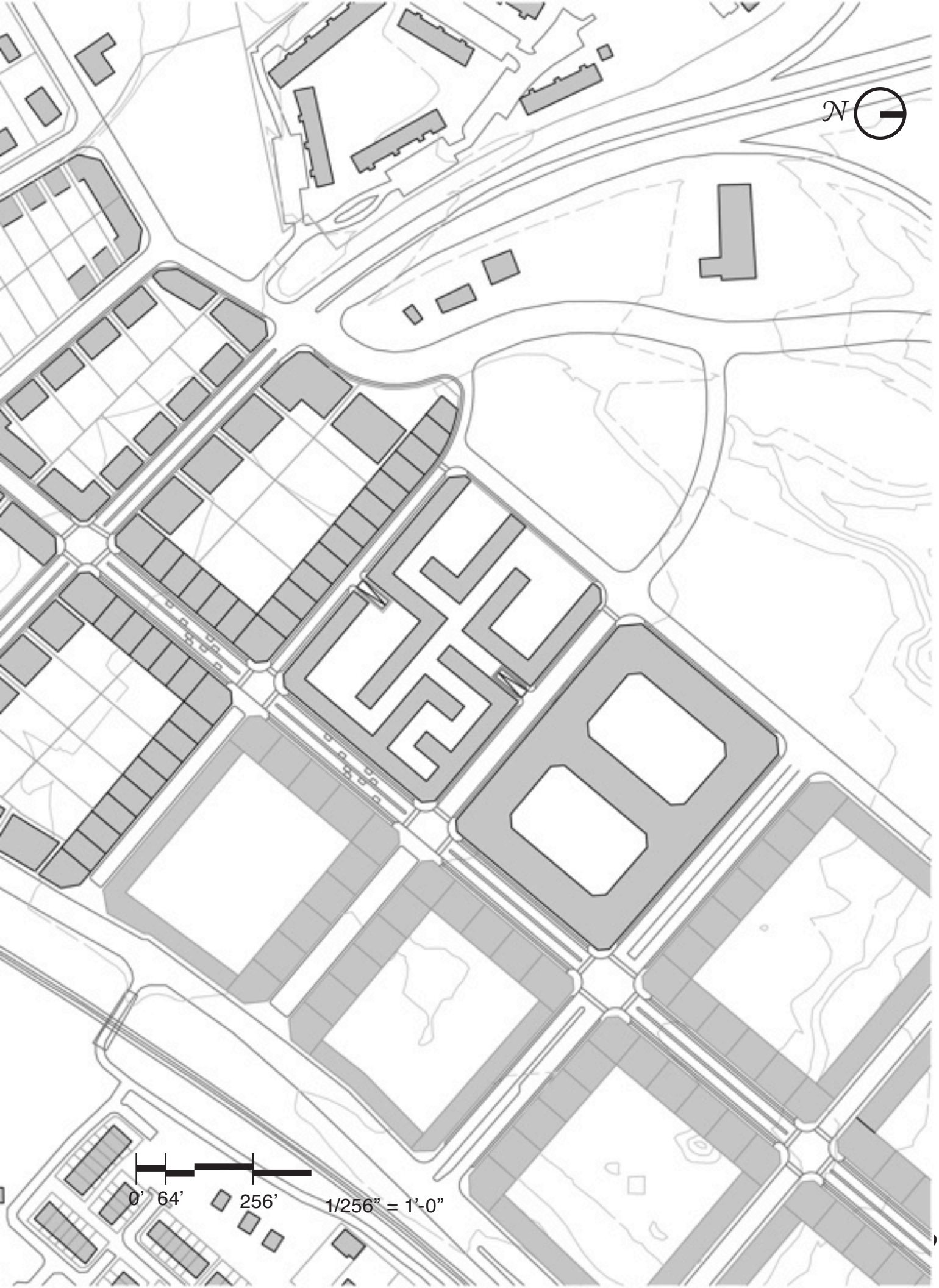
Gross Square Footage: 275,000 sf

Footprint: 68,800 sf

Open Space: 54%

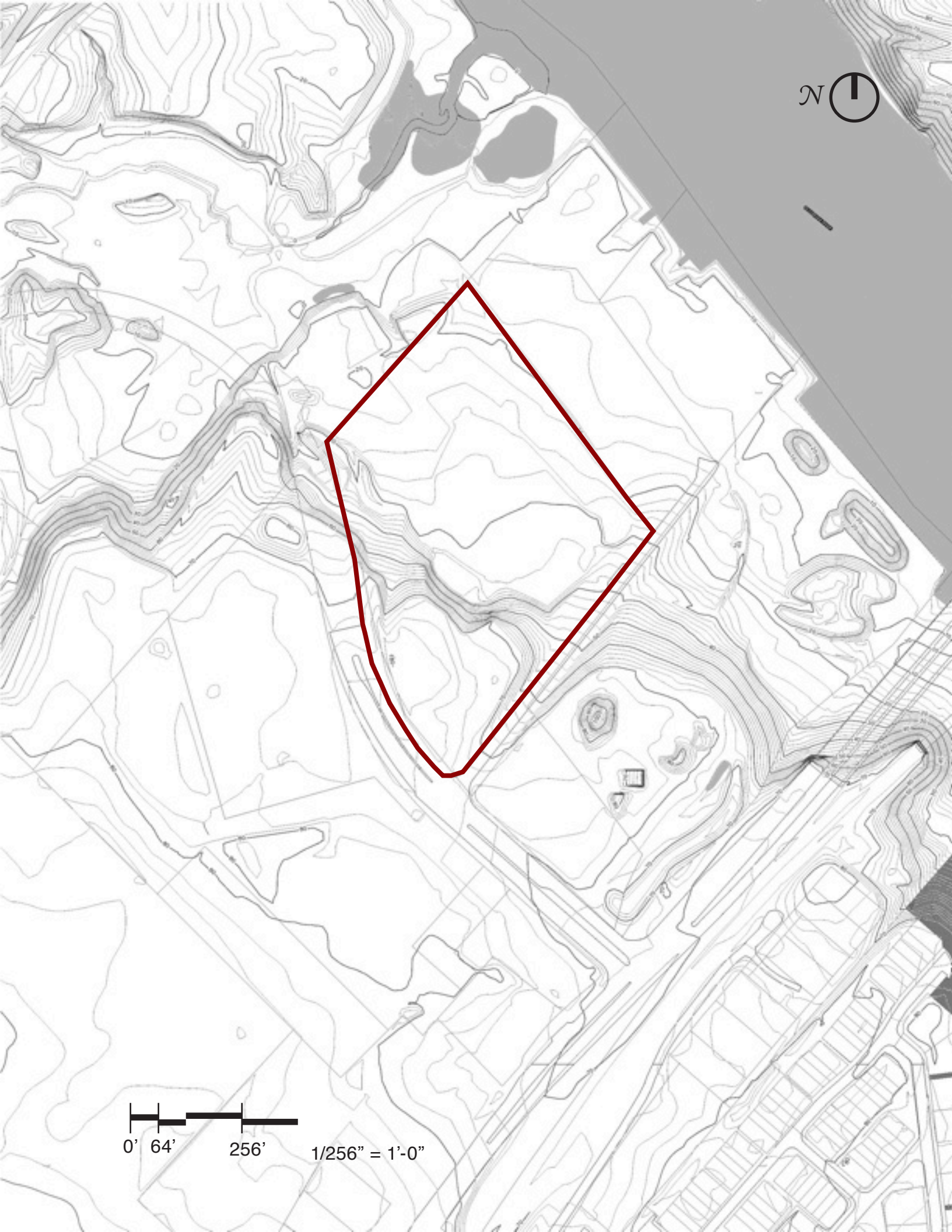
Code Required Open Space: 30%

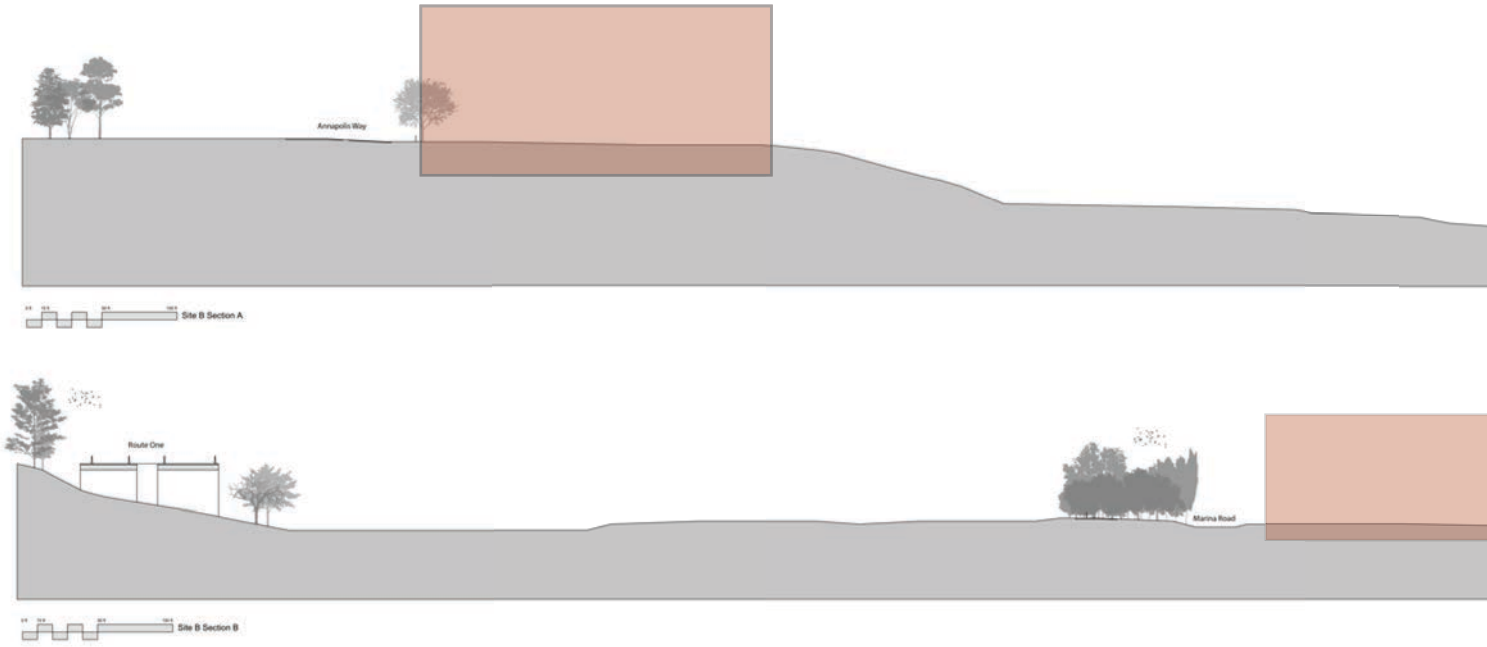
This design could be 24% denser, but sunlight & views to apartments are worth the loss in density.


N
0’ 64’ 256’
1/256” = 1’-0”

Site Topography

area zoned “PMR - Planned Mixed Use” show outlined.


N
0’
64’
256’
1/256” = 1’-0”



The section of the existing conditions on the site, with the specific property outlined in red.


I-95 On ramp

County Charrette

Quick massing studies, from the county's charrette. These serve as food for thought on how I might interpret and mass the site, as they offer insight on what the goals are for the redevelopment.

Walkable Blocks – Conceptual Diagram

Here there is a desire to recreate the fabric of the urban block on the site. This massing would re divide the property lines and alter the streets to assert the new fabric.

Trails and Connections – Conceptual Diagram

In this example, the same urban grid is evident, but there is greater focus on integrating with the existing infrastucture and contextual fabric.

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Site Images

Larger Area Satellite Imagery

As seen in the images, the site and the area around it is dilapidated and unused, hence the county plan to bulldoze and redevelop this highly-trafficked area.

PMR Area

The primary area of the site. Marked by the red dot on the satellite image above.

Nearby Conditions

An area near the site, illustrating dilapidation of the whole area and hence the reason for redevelopment and my choice of the site. Marked on the satellite image with a green dot.

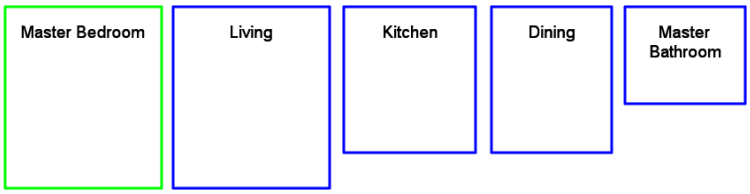
Existing Business area of site

An area at the edge of the site, showing disuse and again the reason for redevelopment to revitalize the community. This image is marked on the map with a green dot.

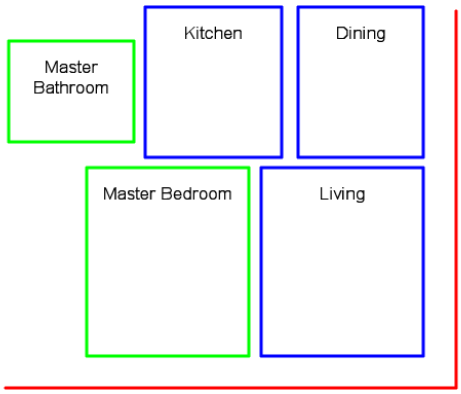
One Bedroom Apartment

Program

Bedroom	15x13	195 sqft	Living	15x13	195 sqft
Bathroom	10x8	80 sqft	Dining	10x12	120 sqft
Kitchen	11x12	132 sqft			
Net Total		**722 sqft**			
Gross Total		**1100 sqft**			



Adjacencies



(Red represents the building envelope, here it does not completely encircle the program because it is in an apartment building and the other borders will be between apartments and open areas)

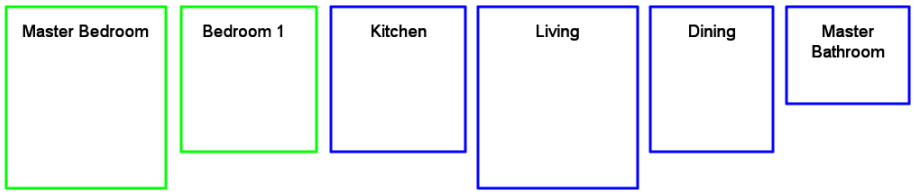
Two Bedroom Apartment

Program

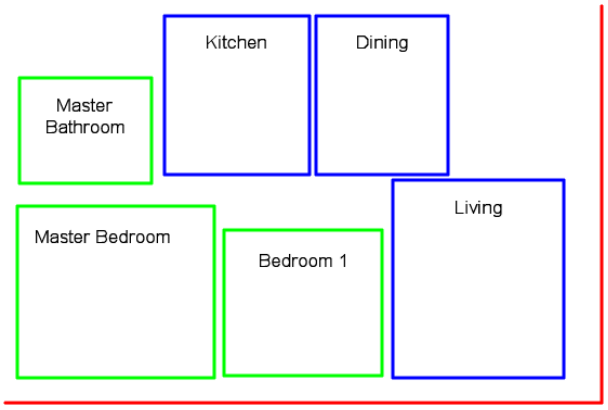
Master Bedroom	15x13	195 sqft	Kitchen	11x12	132 sqft
Bedroom	12x11	132 sqft	Living	15x13	195 sqft
Bathroom	10x8	80 sqft	Dining	12x10	120 sqft

Net Total . . . . . 854 sqft

Gross Total . . . . . 1200 sqft



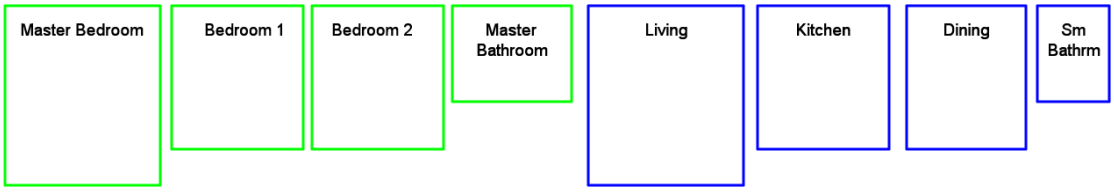
Adjacencies



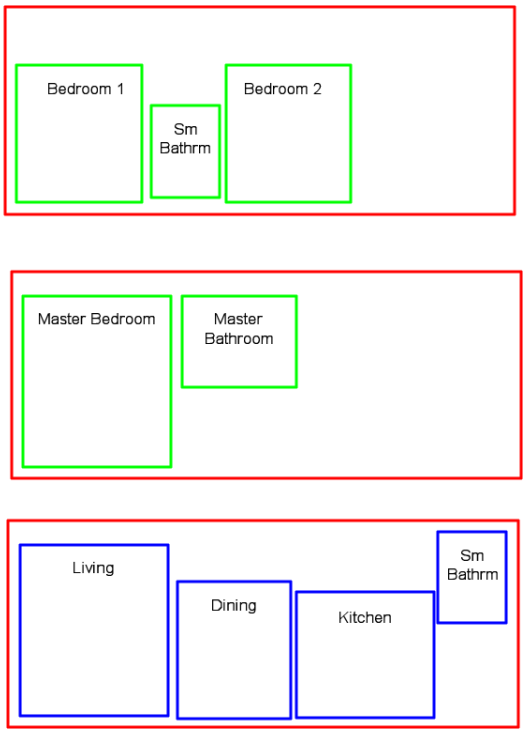
Three Bedroom Townhouse

Program

Master Bedroom	15x13	195 sqft	Kitchen	11x12	132 sqft
Bedroom 1	12x11	132 sqft	Dining	10x12	120 sqft
Bedroom 2	12x11	132 sqft	Small Bathroom	6x8	48 sqft
Living Room	15x13	195 sqft	Master Bathroom	10x8	80 sqft
Net Total		**1034 sqft**			
Gross Total		**1500 sqft**			



Adjacencies



(Red represents the building envelope, here each loop represents a building level for the townhouse type)

Interrelations

In this type, chunks of living unit private space have a distinct threshold when in contact with more public spaces, which themselves compose courtyards and circulation.

Narrative

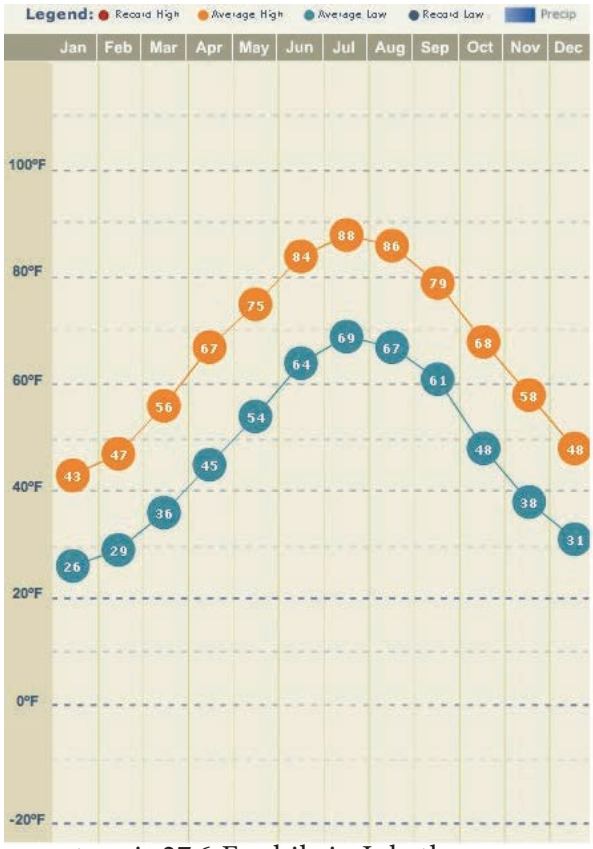
The residents here are new families and young professionals. They have very different schedules and diverse interests.

Adjacencies

Here, we consider the building itself to be the shell for a community instead of the whole site. In that manner, it must address its surroundings in much the same manner as the suburban community described earlier.

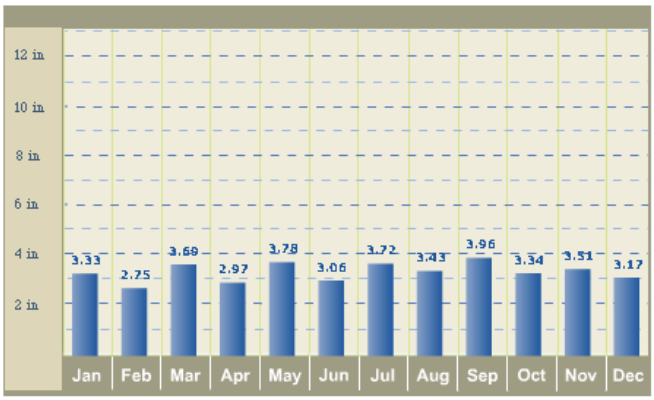
08 General Climate Information

Average Temperature Range



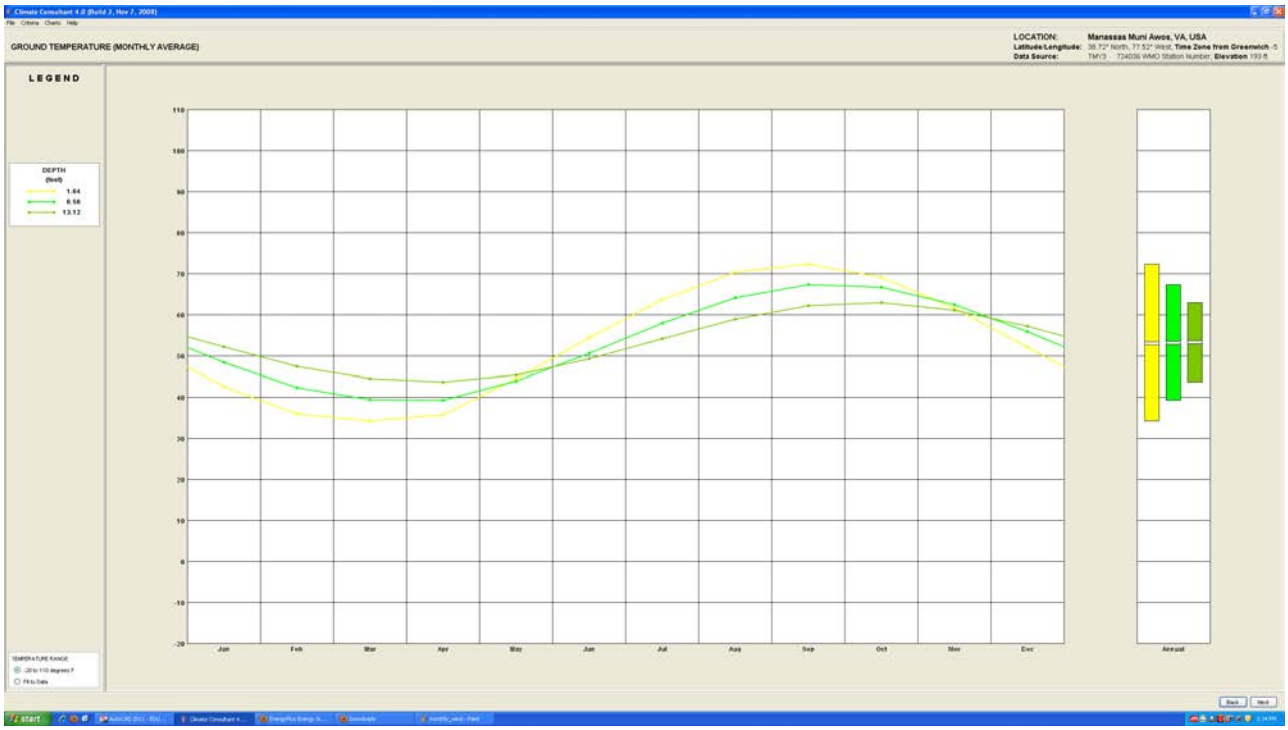
In January the coldest average temperature is 27.6ºF, while in July the average warmest is 87.5ºF.

Average Precipitation

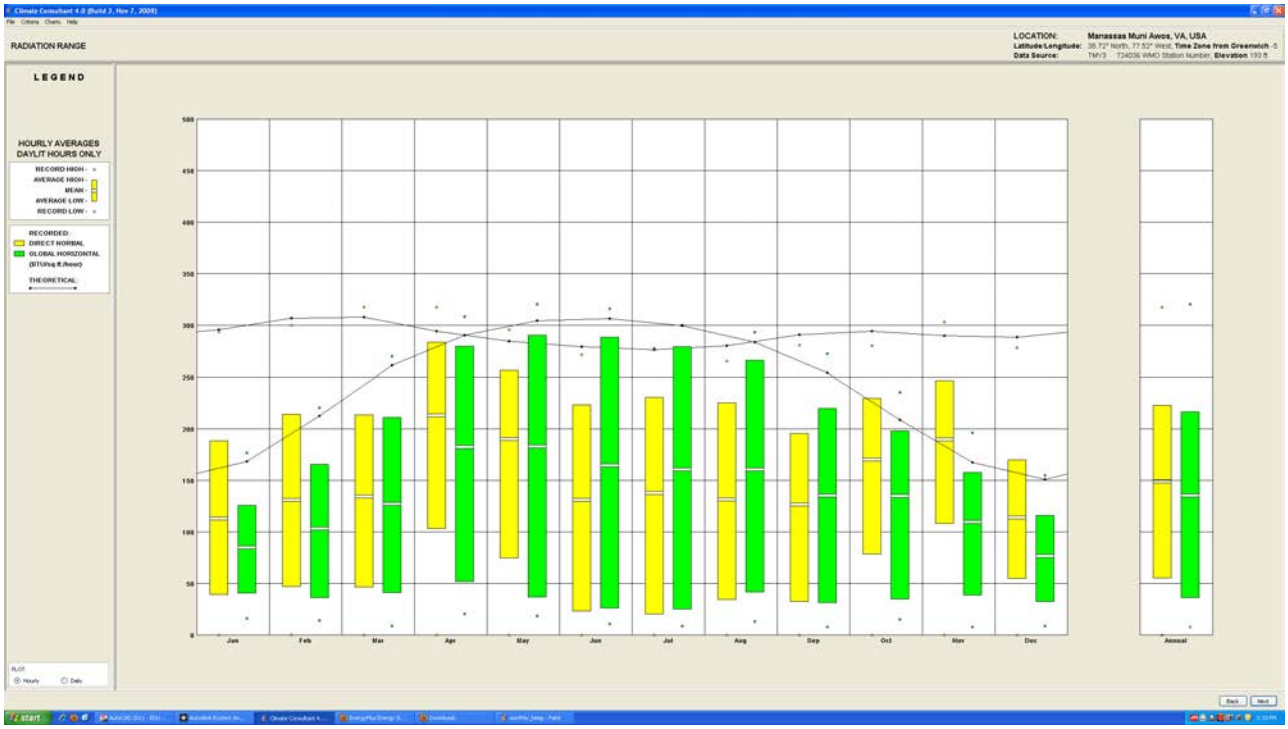


February only gets 2.98 inches, while the wettest month is July with 4.67 inches.

Monthly Ground Temperature

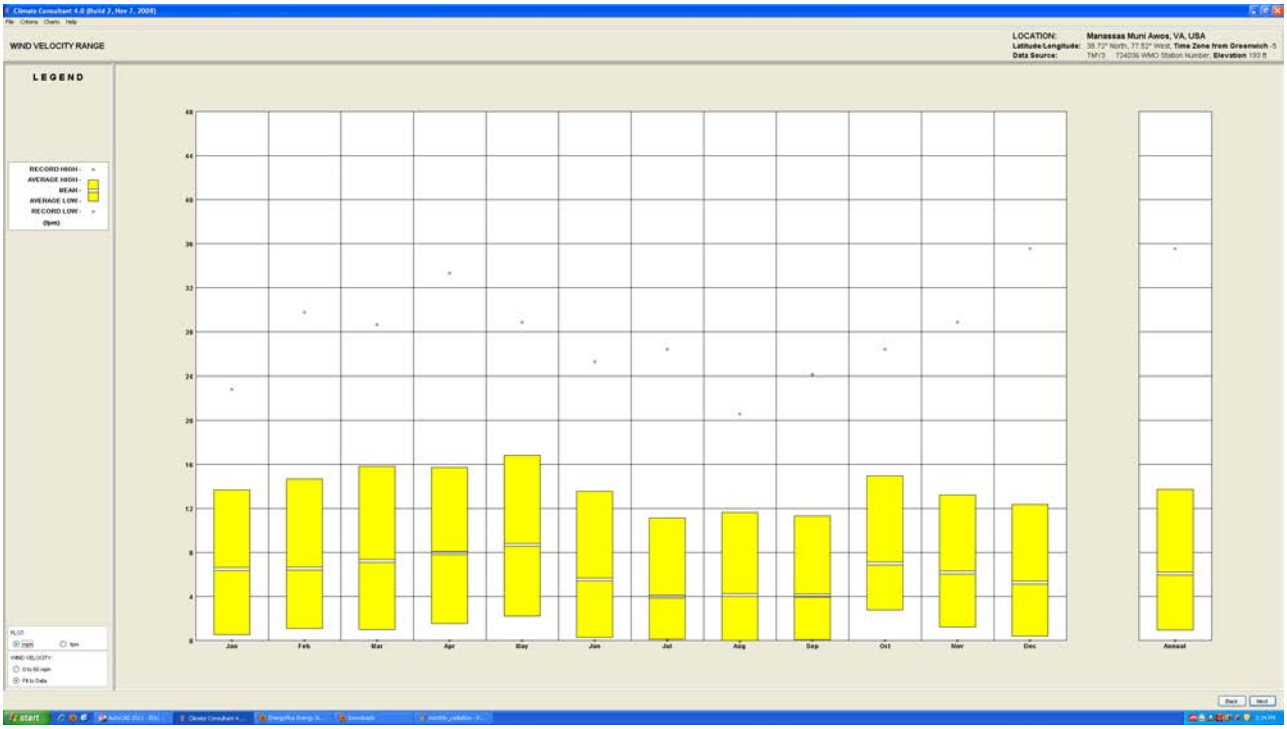


Monthly Solar Radiation

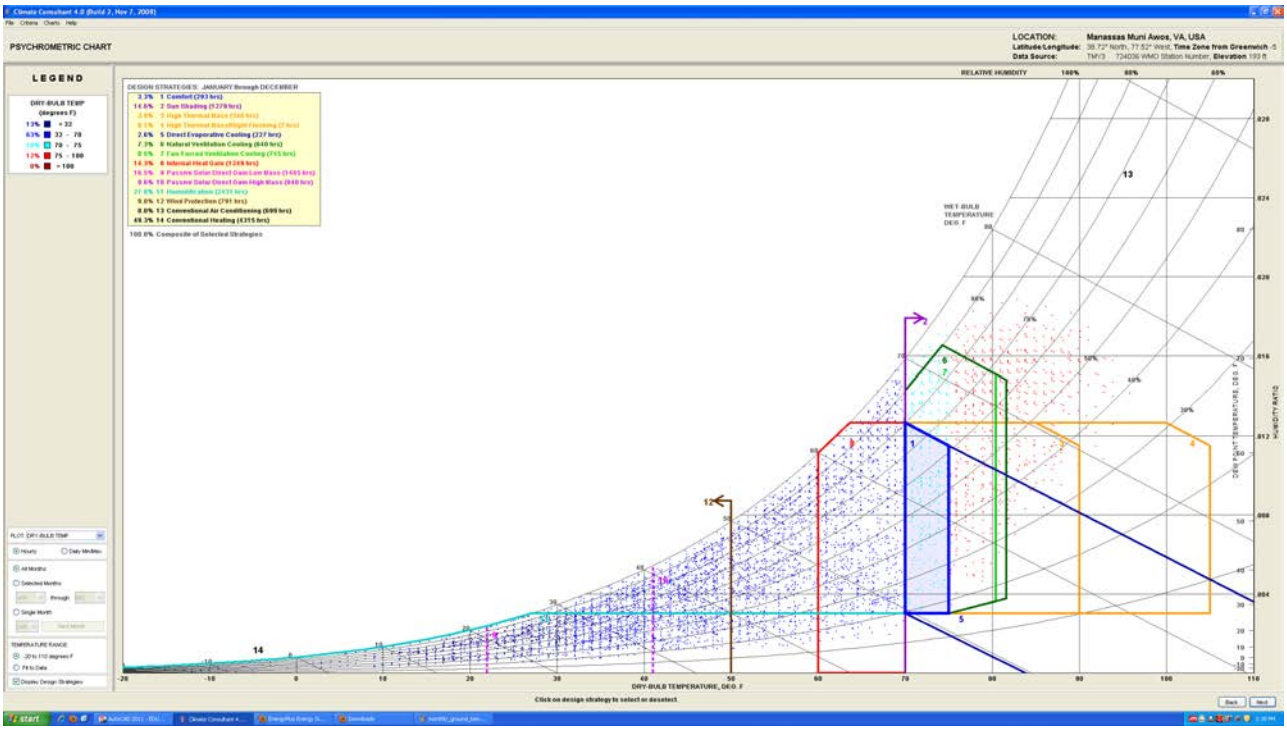


Monthly Temperature Ranges

Monthly Wind



Psychrometric



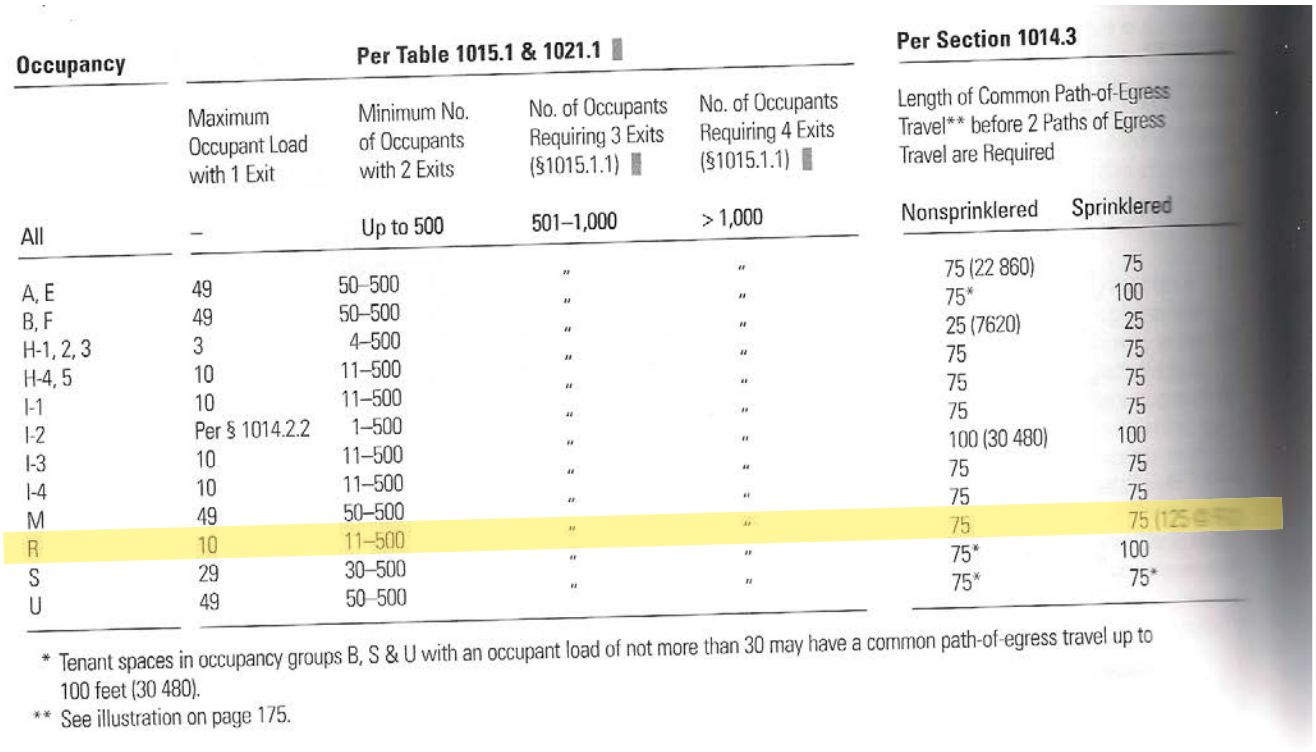
This psychometric chart shows that there are 293 hours during the year where no HVAC intervention is required. There are 4315 hours where conventional heating would be recommended and 699 hours where conventional air-conditioning is recommended. During 791 hours wind protection is needed and 2431 hours humidification. There are 1279 hours where sun shading would be required.

09 Code Regulations

Virginia amends the International Building Code, calling the result the Virginia Uniform Statewide Building Code.

Occupancy Groups

Because of the different scales I am exploring with the different sites, the buildings will fall into different occupancy categories. The single family residences are of the R-3 type, and the apartment buildings are of the R-2 type.



Occupancy	Per Table 1015.1 & 1021.1				Per Section 1014.3	
	Maximum Occupant Load with 1 Exit	Minimum No. of Occupants with 2 Exits	No. of Occupants Requiring 3 Exits (§1015.1.1)	No. of Occupants Requiring 4 Exits (§1015.1.1)	Length of Common Path-of-Egress Travel** before 2 Paths of Egress Travel are Required	
All	–	Up to 500	501–1,000	> 1,000	Nonsprinklered	Sprinklered
A, E	49	50–500	"	"	75 (22 860)	75
B, F	49	50–500	"	"	75*	100
H-1, 2, 3	3	4–500	"	"	25 (7620)	25
H-4, 5	10	11–500	"	"	75	75
I-1	10	11–500	"	"	75	75
I-2	Per § 1014.2.2	1–500	"	"	75	75
I-3	10	11–500	"	"	100 (30 480)	100
I-4	10	11–500	"	"	75	75
M	49	50–500	"	"	75	75
R	10	11–500	"	"	75	75 (125 @
S	29	30–500	"	"	75*	100
U	49	50–500	"	"	75*	75*

* Tenant spaces in occupancy groups B, S & U with an occupant load of not more than 30 may have a common path-of-egress travel up to 100 feet (30 480).

** See illustration on page 175.

176 / BUILDING CODES ILLUSTRATED

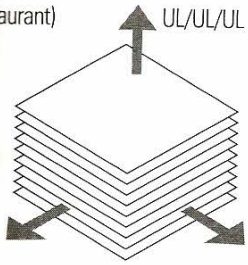
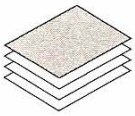
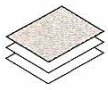
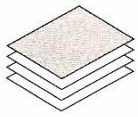
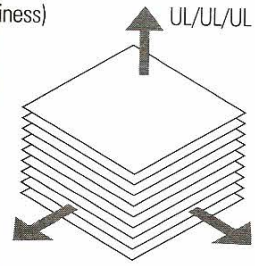
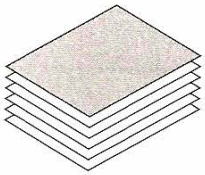
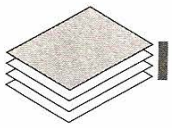
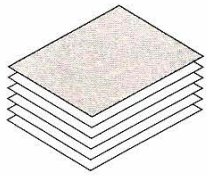
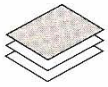
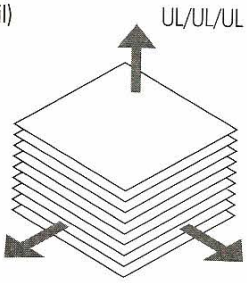
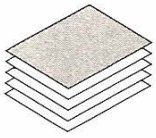
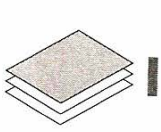
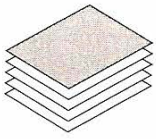
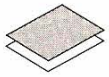
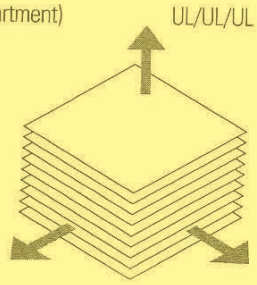
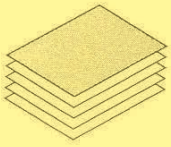
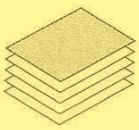
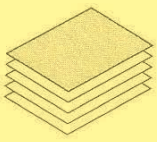
As shown in Building Codes Illustrated, this occupancy group, R, is allowed a maximum occupant load of 10 with 1 exit; 11-500 with 2 exits. It is allowed to have a 75' length nonsprinklered common path-of-egress before two paths of egress are required; the distance is still 75' if the path is sprinklered, but is 125' if the occupancy group is specifically R-2, and the path is sprinklered.

Occupancy	Corridor Required for Occupant Load	Fire-Resistance Rating Without Sprinklers	Fire-Resistance Rating With Sprinklers	Notes	Dead-End Distance [20' (6096) typical]	Minimum Corridor Width Per § 1018.2 [44" (1118) typical]
A, B, F, M, S, U	>30	1	0	No rating required in open parking garages per § 1018.2, Exc. 3	50' (15 240) @ B, E, F, I-1, M, R-1, R-2, R-4, S & U when sprinklered	72" (1829) in corridors serving gurney traffic in outpatient medical occupancies where patients are not capable of self-preservation
B	>30 ≤49	1 0 (only 1 exit required per §1015.1)	0			
E	>30	1	0	No rating if at least one door in each room used for instruction opens directly to the outside and if used for assembly, room has at least one-half of the required means-of-egress doors opening directly to the exterior		72" (1829) when occupant capacity >100; § 1018.2, Exc. 4
R	>10	Not permitted	1/2 hour	No rating at corridors inside dwelling unit or sleeping unit		36" (914) within dwelling unit
H-1, H-2, H-3	All	Not permitted	1			
H-4, H-5	>30	Not permitted	1			
I-2[1], I-4	All	Not permitted	0	1. See § 407.3 for I-2		72" (1829) when serving I-occupants not capable of self-preservation; 96" (2438) in I-2 when required for bed movement
I-1, I-3	All	Not permitted	1 [2]	2. See § 408.7	50' (15 240); see § 1018.4, Exception 1 (only @ I-3)	I-occupants not capable of self-preservation
All					Unlimited when dead-end is less than 2 1/2 times least corridor width	24" (610) typical for mechanical access; 36" (914) with < 50 occupants

For this occupancy group, a corridor is required when the occupant load is greater than 10. The corridor is required to be sprinklered at that point. THe fire resistance rating of the sprinklered corridor must be 1/2 hour. The minimum corridor width is 38" within a dwelling unit.

TABLE 503

Excerpt from IBC Table 503 (Showing allowable building height, number of stories and proportionate floor areas per story)

Construction Type (See Table 601)	Type I A Fire-Rated	Type II A Fire-Rated	Type III B Partially rated	Type IV Heavy Timber	Type V B Nonrated
Occupancy					
A-2 (Restaurant)	UL/UL/UL 	65/3/15,500 sf 19.8 m/3/(1440 m²) 	55/2/9,500 sf 16.8 m/2/(883 m²) 	65/3/15,000 sf 19.8 m/3/(1394 m²) 	40/1/6,000 sf 12.2 m/1/(557 m²) 
B (Business)	UL/UL/UL 	65/5/37,500 sf 19.8 m/5/(3484 m²) 	55/3/19,000 sf 16.8 m/4/(1765 m²) 	65/5/36,000 sf 19.8 m/5/(3344 m²) 	40/2/9,000 sf 12.2 m/2/(836 m²) 
M (Retail)	UL/UL/UL 	65/4/21,500 sf 19.8 m/4/(1997 m²) 	55/2/12,500 sf 16.8 m/4/(1161 m²) 	65/4/20,500 sf 19.8 m/4/(1904 m²) 	40/1/9,000 sf 12.2 m/1/(836 m²) 
R-2 (Apartment)	UL/UL/UL 	65/4/24,000 sf 19.8 m/4/(2230 m²) 	55/4/16,000 sf 16.8 m/4/(1486 m²) 	65/4/20,500 sf 19.8 m/4/(1904 m²) 	40/2/7,000 sf 12.2 m/2/(650 m²) 

This table from Building Codes Illustrated, which itself is an excerpt from the International Building Code, shows the allowable building height, the maximum number of stories and the proportionate floor area per story.

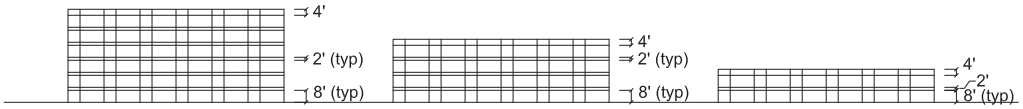
This thesis belongs to the group R-2, and so with a construction type of 1A/Fire-Rated, the building height and floor area is un limited by the fire code.

With a construction type of 2A/ Fire-Rated, there is a maximum of 65' in height and 4 stories. Type 3B/ partially Rated allows up to 55' with 4 stories. Type 4/Heavy Timber allows up to 55' and 4 stories. Type V/B/Non rated allows only 40' and 2 stories.

10 Final Product

To develop a building system which can be dissasembled and reassembled so that a building's materials can be reused at the building's end of life, and that the internal configuration can be altered by the occupant with minimal effort. The program for this system is a residential apartment building in a mid-rise context (up to six stories). The system's modules will only be designed to be reused to construct residential scale buildings in the same climate region.

"Only when individuals can make their own decisions concerning the plan and equipment of thier dwelling can the dwelling be expected to truly reflect personal aspirations." - N J Habraken

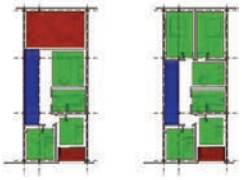


6 Levels (3 units high)

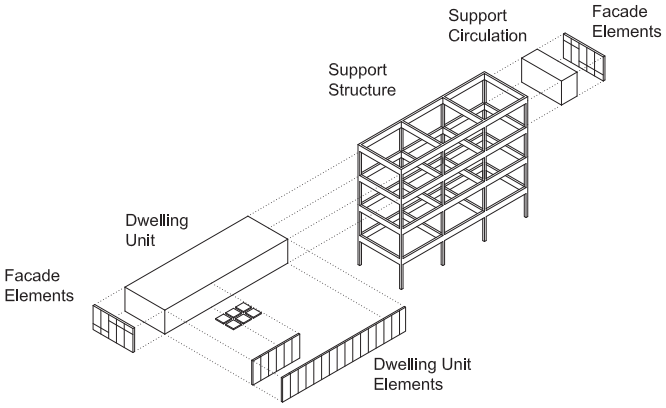
4 Levels

2 Levels

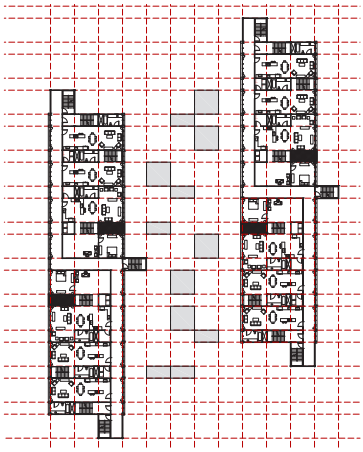
Minimum space between buildings,
Living space never faces another living space



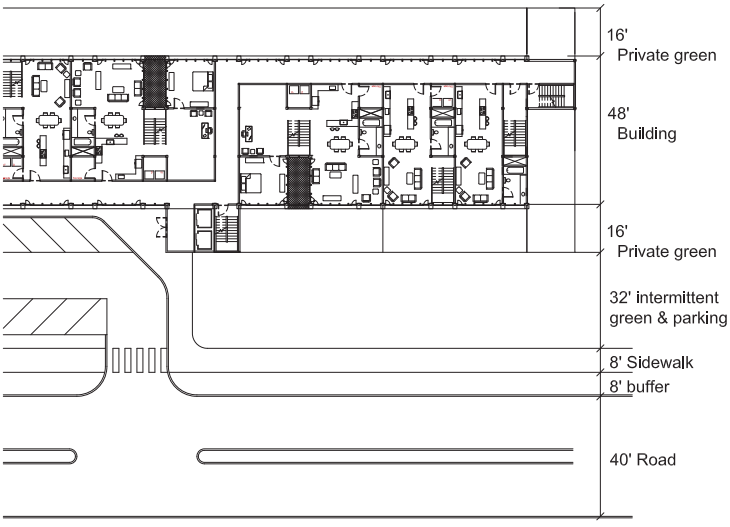
Units allow variation



Support vs dwelling

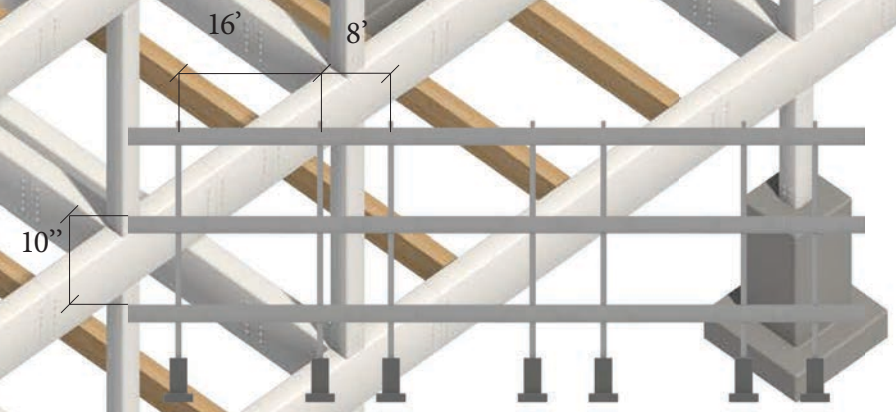


Support grid informs landscaping

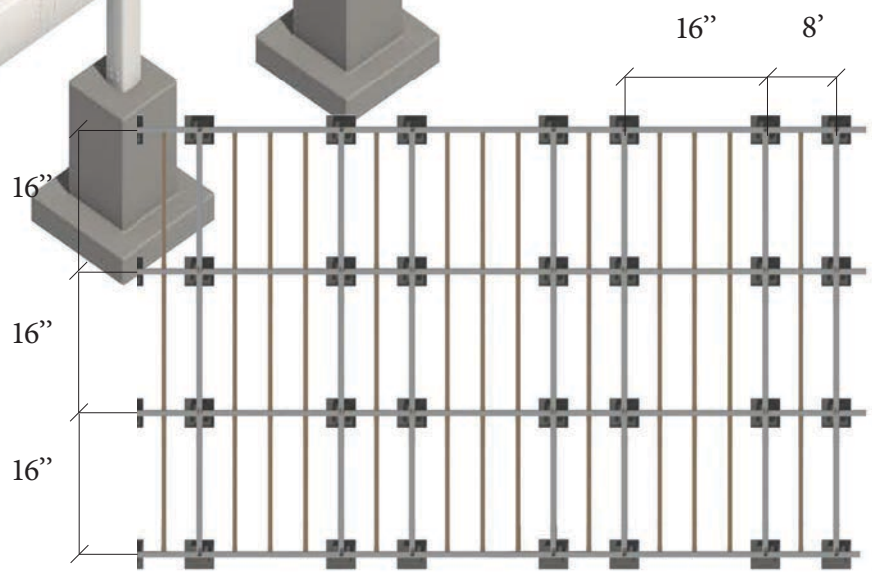


10 Grid Module

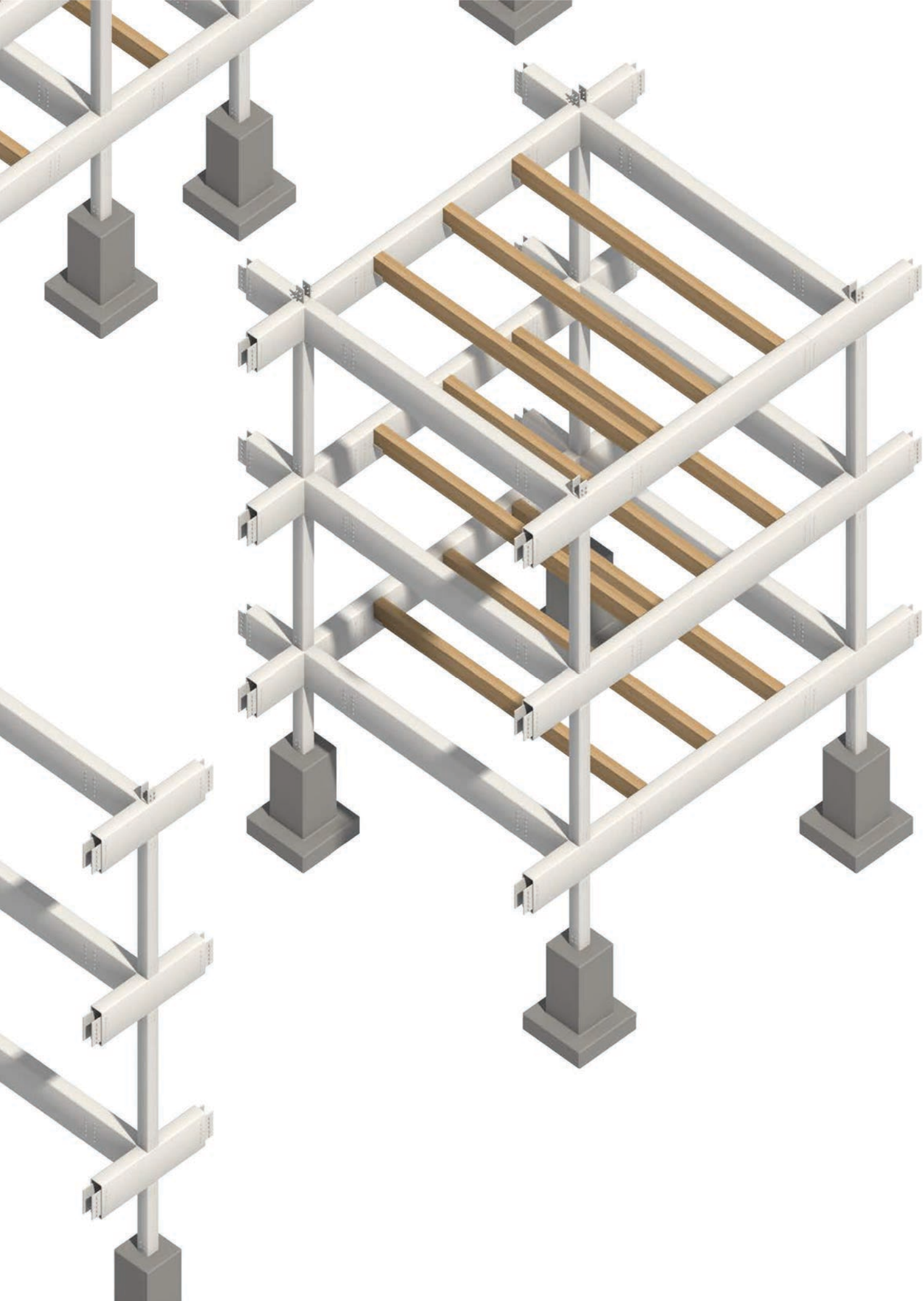
The primary rhythm of the program is established by the structural grid, which is composed of large and small bays, which accommodate differing scales of program. A 16’ span is chosen for the larger bays, allowing living rooms and other shared spaces a spacious area to work with. The smaller span is 8’ which adds some rigidity to the structure while providing adequate space for secondary program and vertical chase.



Structural System Elevation



Structural System Plan

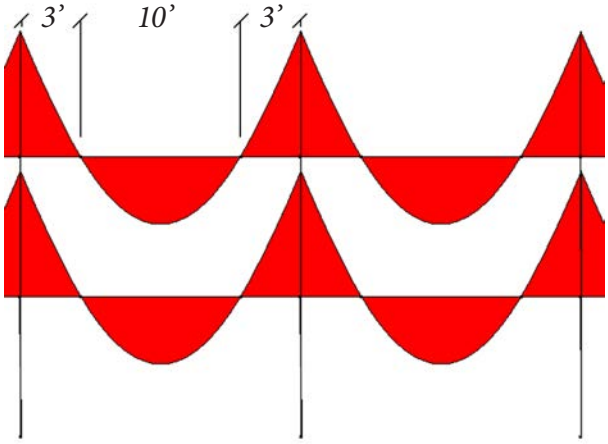


11 Structural Components

The structural system is built up with a small set of components which can be configured to create a variety or rhythmic and massing options for the structure. In the Apartment example i explore in this thesis, we use these components to create a double rhythm of 8' and 16' intervals. The majority of these spacial modules are created with just six different components:

- 8' tall 8x8 HSS column (variable wall thickness)
- 8x24 HSS Beam - 10' long
- 8x24 HSS Beam - 2' long
- 4-Way Welded 8x24 HSS Connector
- 3-Way Welded 8x24 HSS Connector
- 2-Way Welded 8x24 HSS Connector

In addition there are short columns for connecting with foundation pours and timber beams for exposed interior support.



The Welded connector pieces are specially constructed elements which provide bolted connections for the beams and columns. When the beams are joined to the connector pieces they form a continuous beam with the connections (bolted) at the point of least bending moment.

Timber beams pass loads from floor modules into main HSS structure

4-way connector bolts together with columns and beams

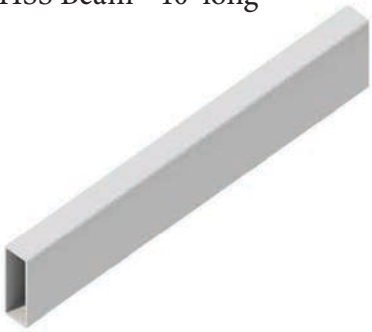
Timber Beams

4-Way HSS Connector

8x8 HSS Column - 8’ tall

3-Way HSS Connector

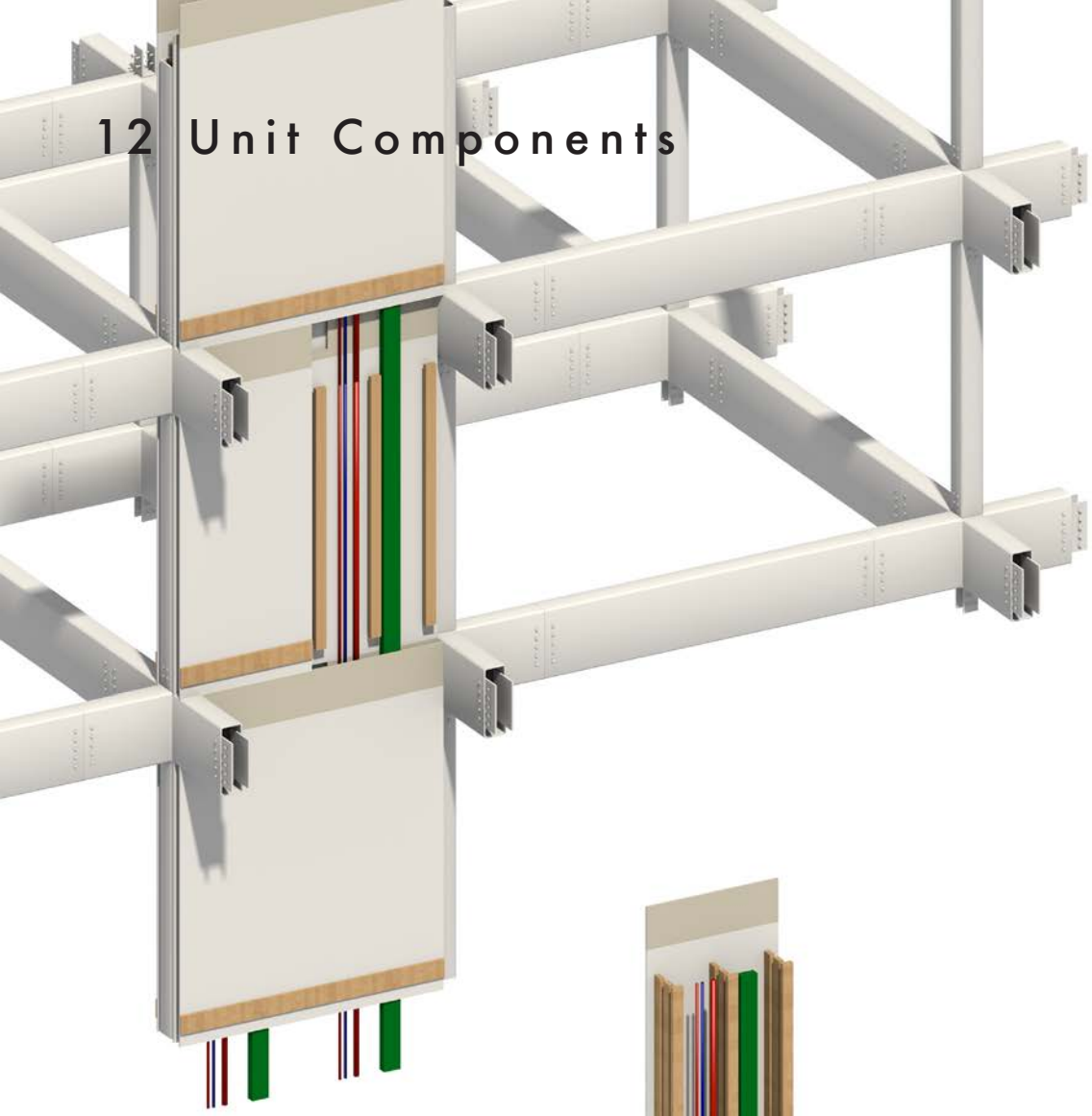
8x24 HSS Beam - 10’ long



8x8 HSS Column - 4’ tall

Foundation

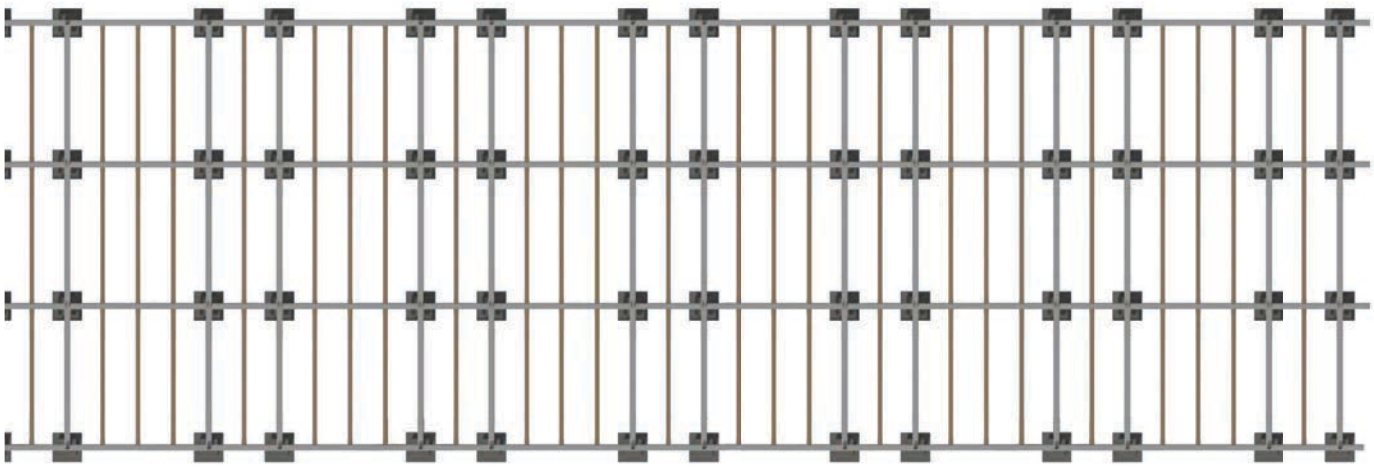
12 Unit Components



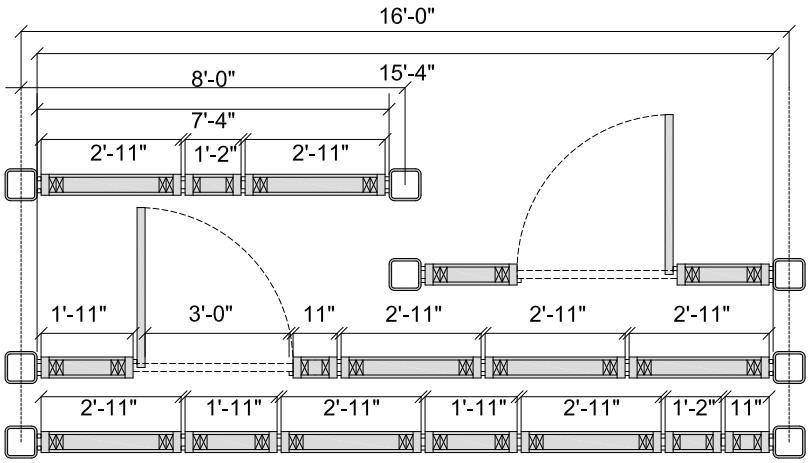
Parti Wall Modules

Vertical riser module

Various Wall modules divide units from one another and allow tenants to control the placement of partition walls within an apartment. Plumbing walls allow for vertical distribution of services in walls adjacent to the 8x16' grid modules, and water closets and kitchens can be extended off of that space.



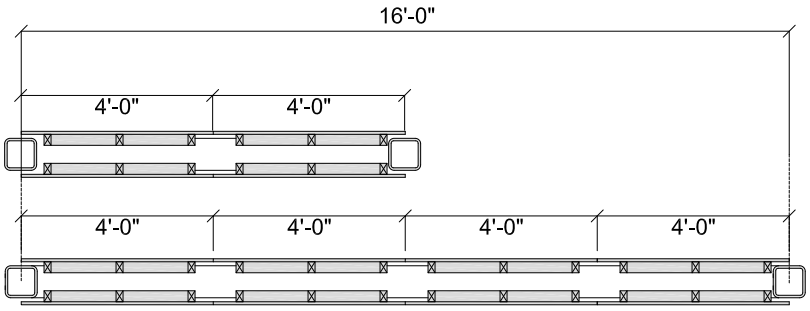
Partition Wall Modules



Partition Walls Detail Section

1/4” = 1’-0”

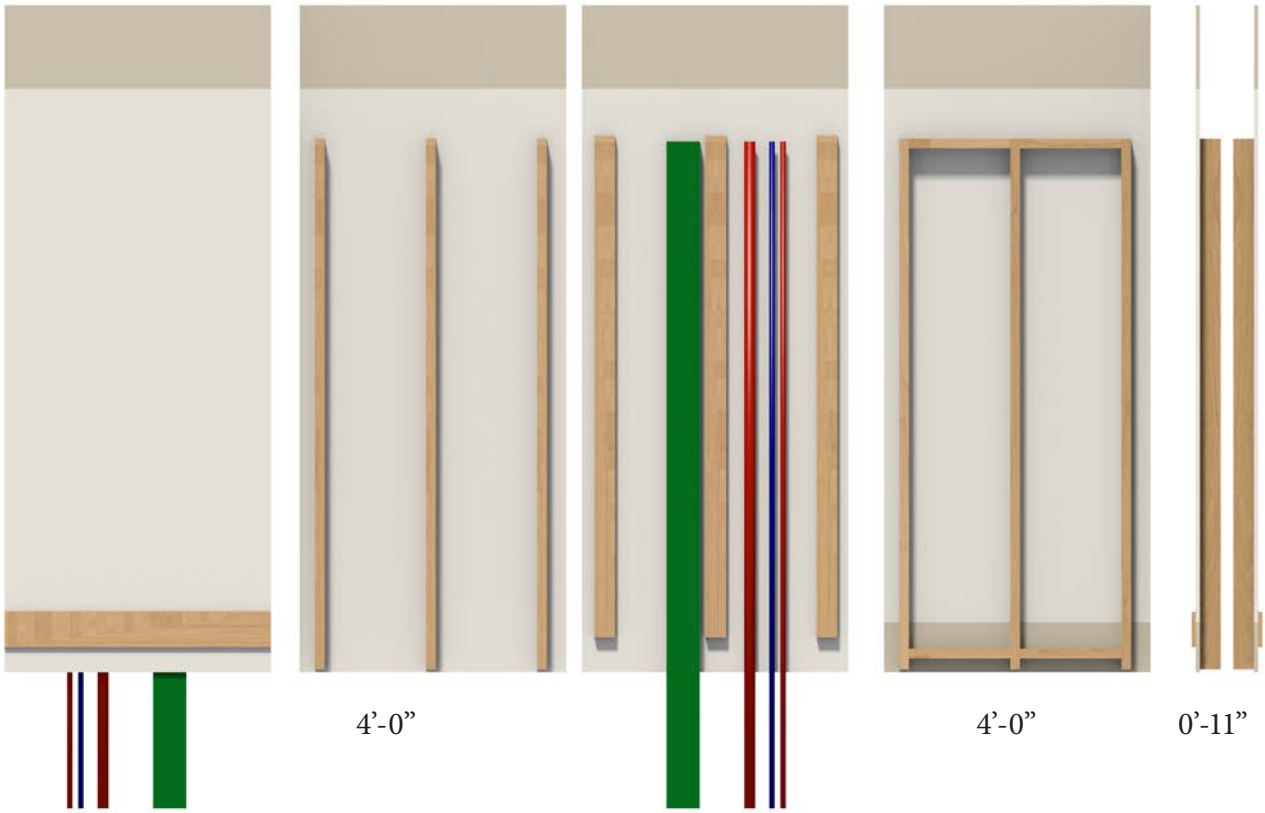
Various sizes of partition panels for inside of the apartments allow tenets to build up any necessary length of wall within the 16’ span between columns.



Fire-rated sheetrock mounted to light wood framing, attatched via bolts to angles on the support beam above. Cavity filled with cellulose insulation.

Parti Walls Detail Section

1/4” = 1’-0”

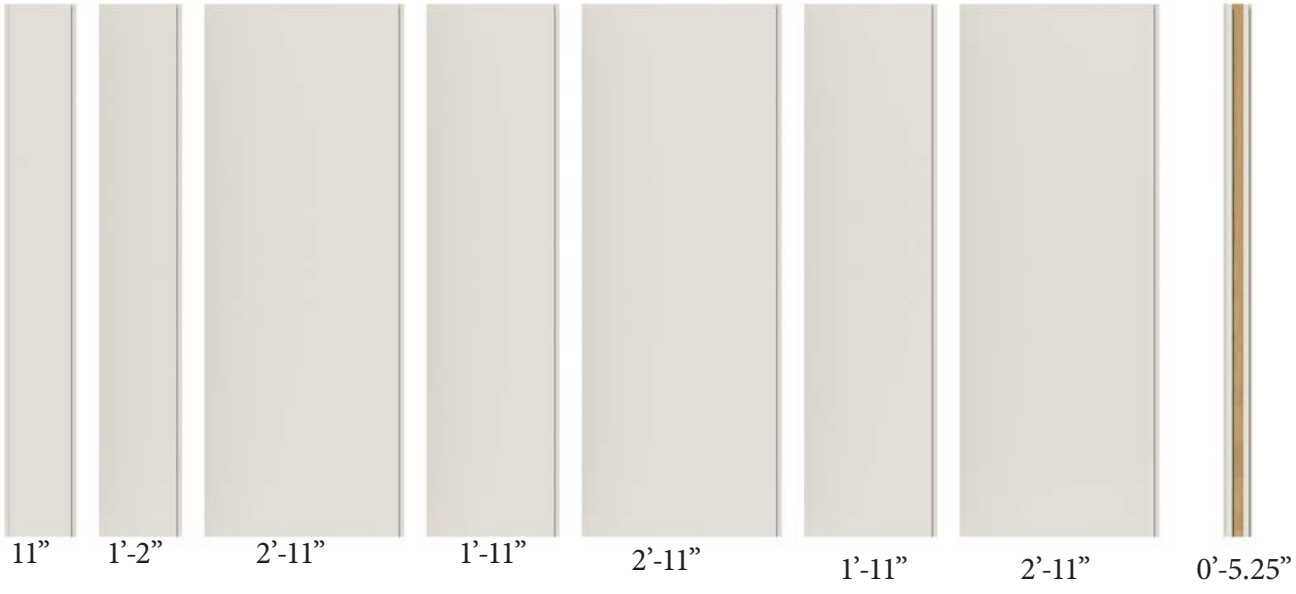


Plumbing wall module,

full, half and with piping.

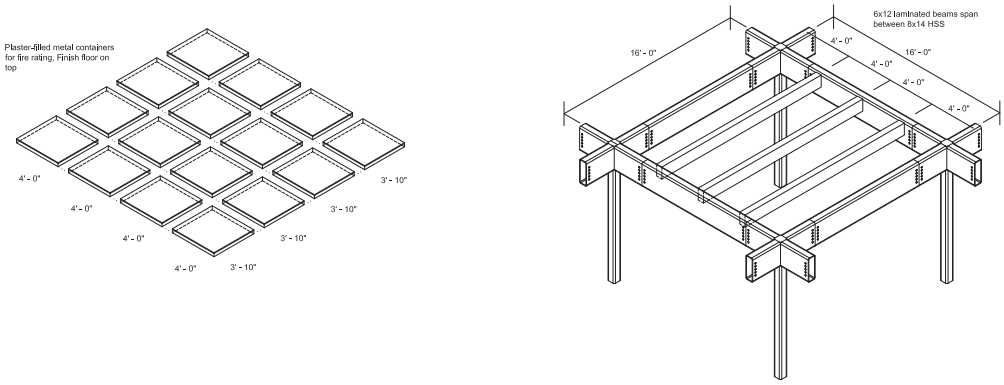
Parti Wall Module,

half and side



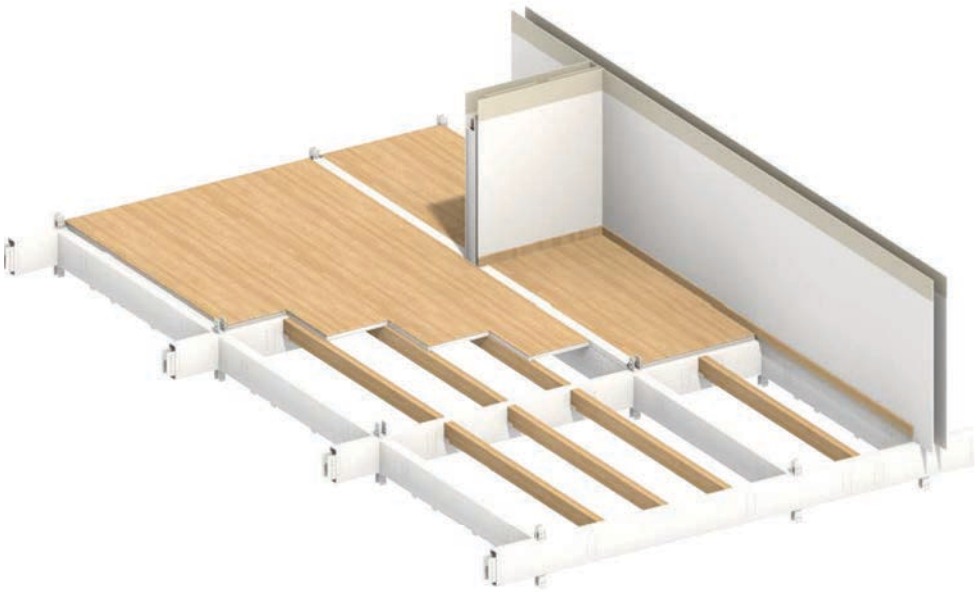
Partition Wall Module,

Various sizes, and side view



Floor Panels & Structure - Axon

1/16” = 1’-0”



Floor Panels & Structure - Axon

Unit axon showing two bays (one 16’ and one 8’) with timber beams and wood floor panels.

0’-4”

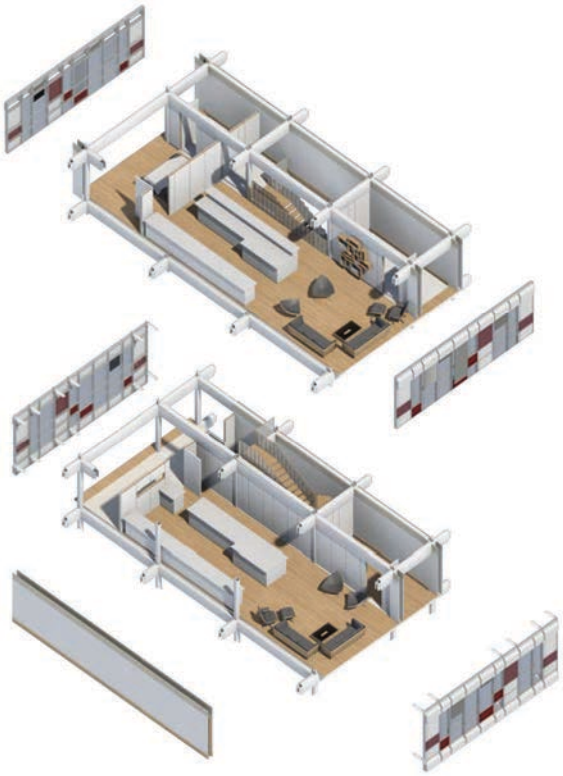
3’-10”

4’-0”

Floor Panel Module,

Top and side.

13 Units & Variations



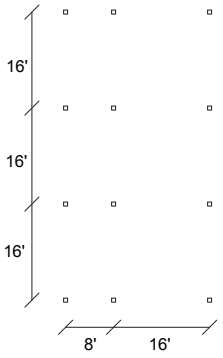
Each “unit” occupies a certain number of bays, both vertically and horizontally, such that different units can accommodate differently sized families and budgets.

In the example building massing I utilize for this project’s site, the building uses a skip-stop corridor so that apartments can be two stories and take advantage of both sides of the building on their second floor. However, this creates a limitation that all units must be two stories.

I created three example unit sizes, ranging from smaller to quite large. In this first example the unit is divided into two separate studio apartments to show how the above mentioned limitation could be resolved if needed.

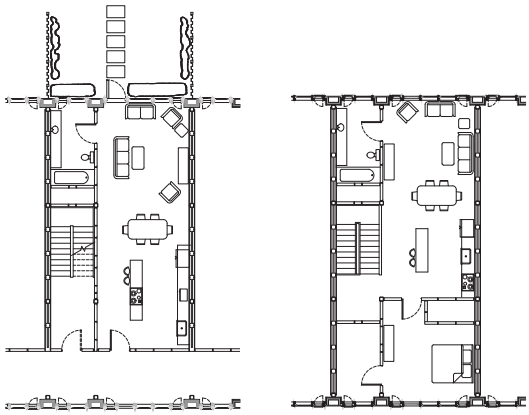
Axon

1/32” = 1’-0”



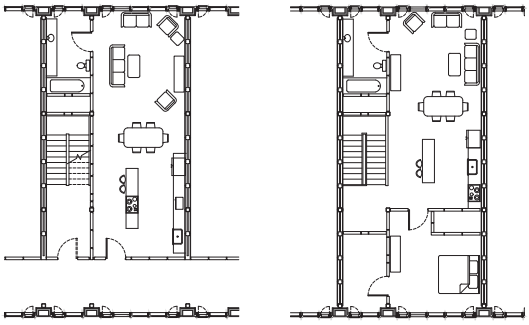
Structural

1/32” = 1’-0”



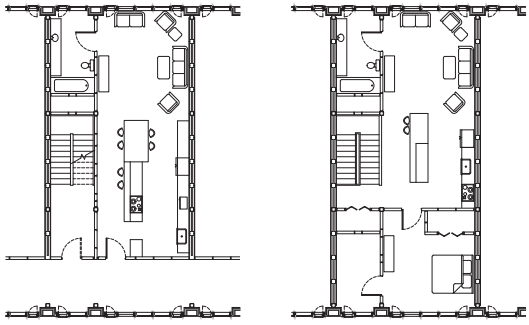
Ground Floor Variation

1/32” = 1’-0”



Variation A

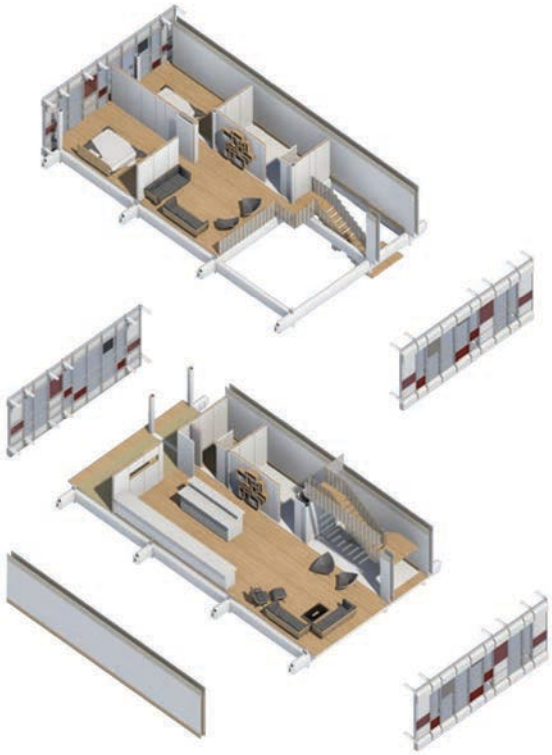
1/32” = 1’-0”



Variation B

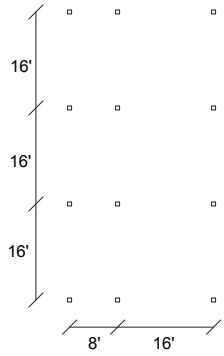
1/32” = 1’-0”

A two story unit with either two or three bedrooms on either the ground floor or on above floors in a multi-story apartment building.



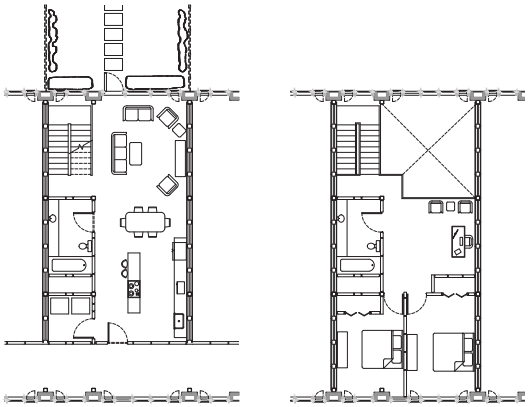
Axon

1/32” = 1’-0”



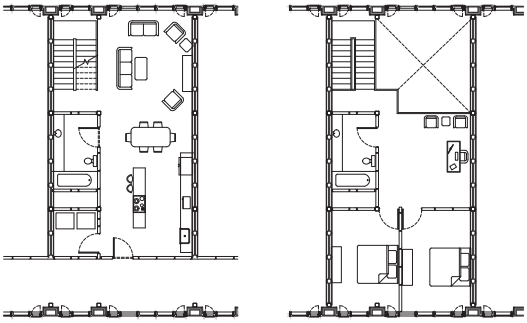
Structural

1/32” = 1’-0”



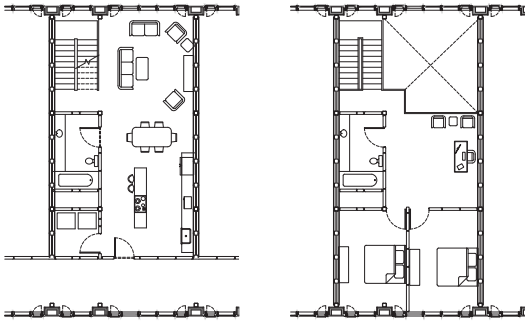
Ground Floor Variation

1/32” = 1’-0”



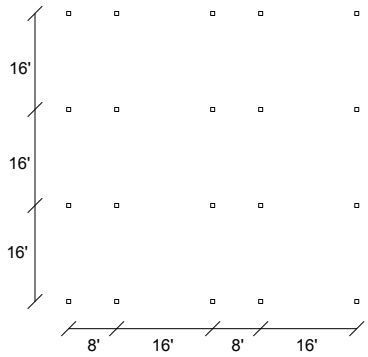
Variation A

1/32” = 1’-0”



Variation B

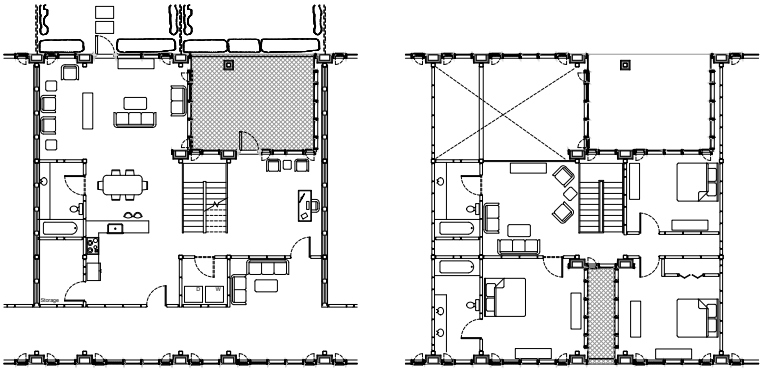
1/32” = 1’-0”



Structural

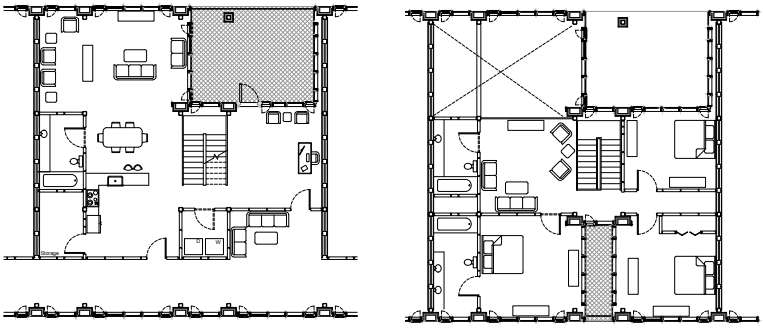
1/32” = 1’-0”

A two story unit with between two and four bedrooms in an apartment skip-stop configuration.



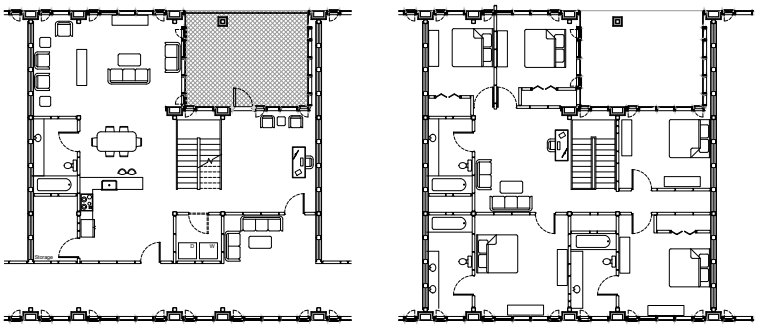
Ground Floor Variation

1/32” = 1’-0”



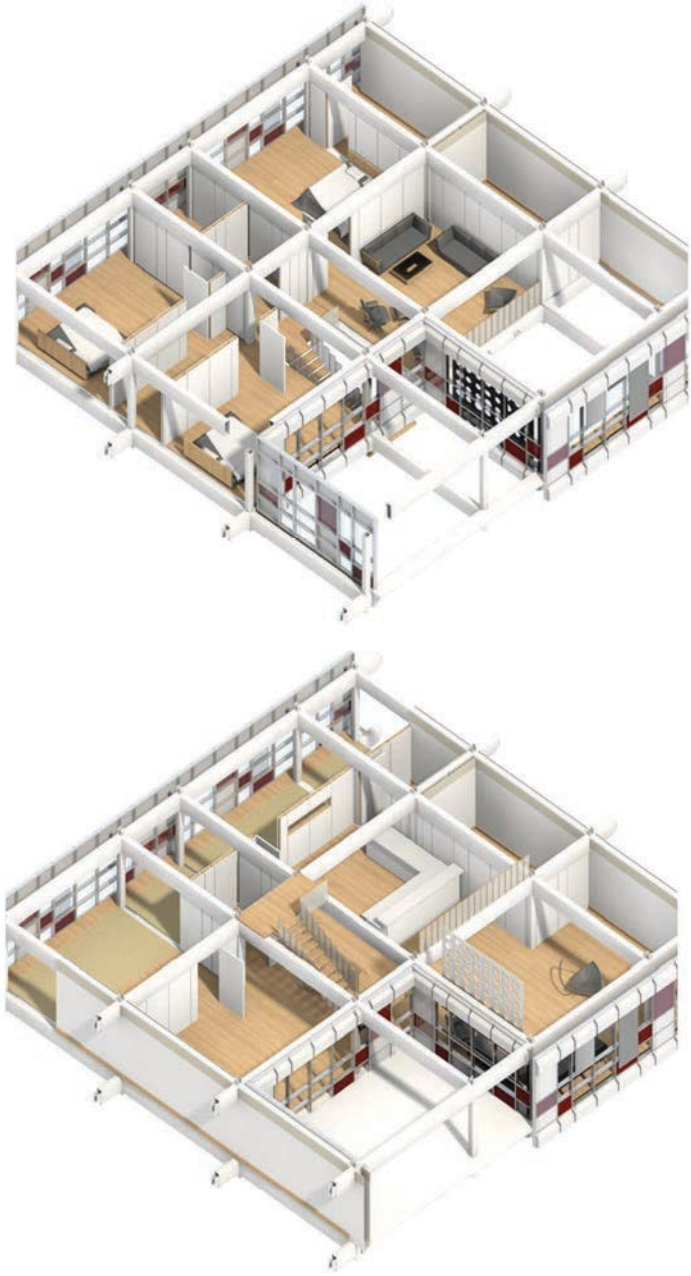
Variation A

1/32” = 1’-0”



Variation B

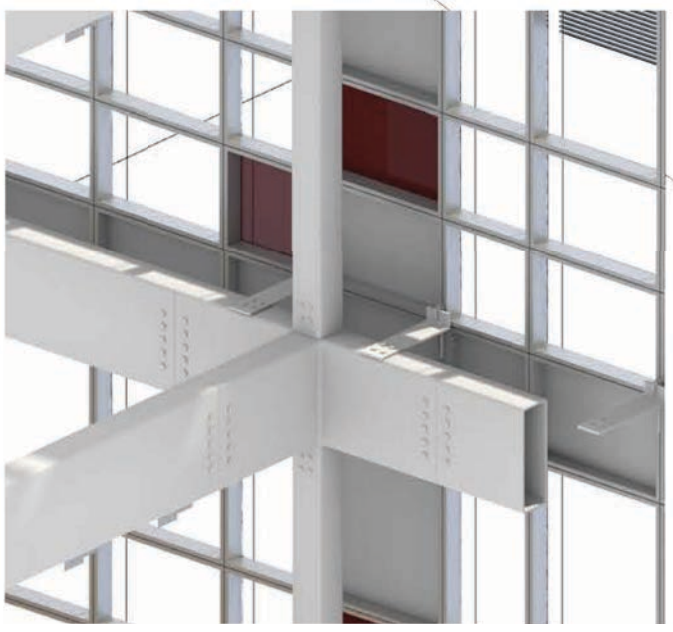
1/32” = 1’-0”



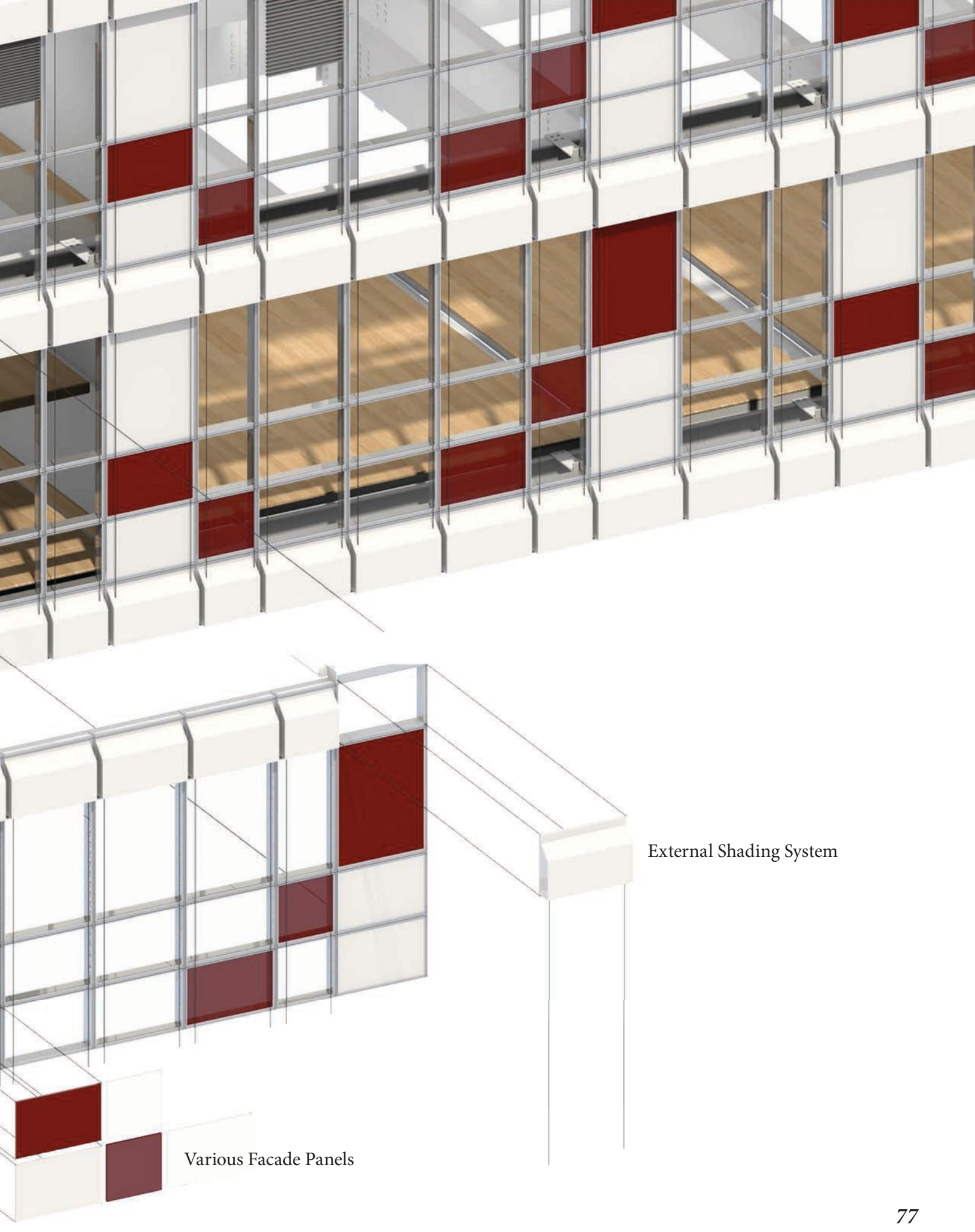
Axon

1/32” = 1’-0”

14 Facade System

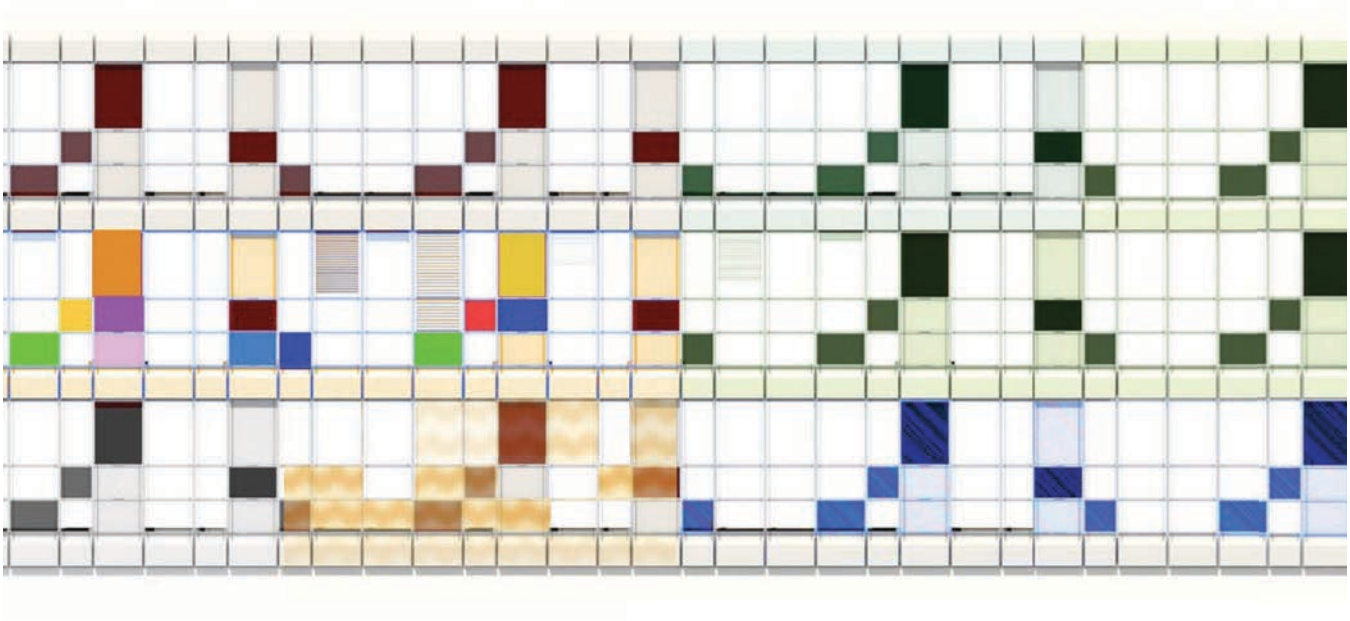


Mullions hung
from structure

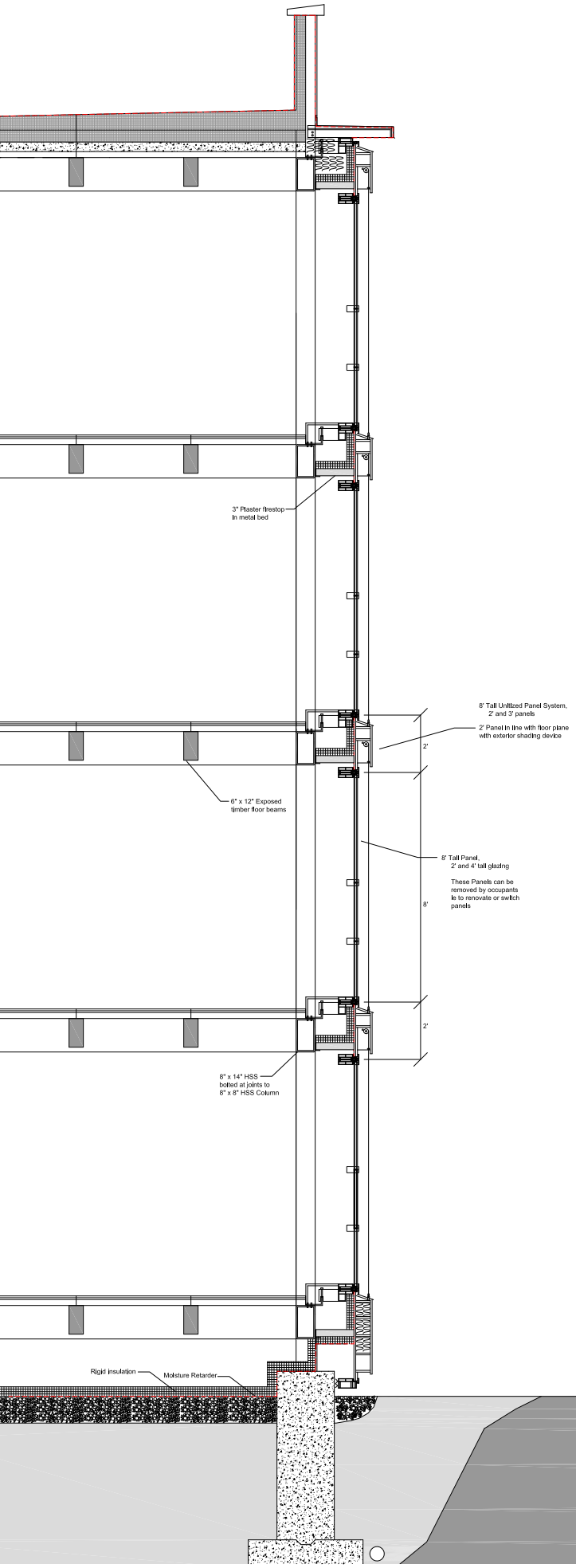

External Shading System
Various Facade Panels

The facade system is a unitized panel system, this allows the panels to be manufactured with great precision and efficiency in a factory and assembled into the facade system very quickly on site, minimizing construction time. A unitized system is ideal for this thesis because the panels could be removed from a unit and customized or by the tenant, they could change out the panels for various operable, inoperable and degrees of opacity.

Each unit's facade could be a unique and distinct display allowing the occupant to fully possess and control the identity of their space.



The Student Village (Olympian Athelete Housing) at the Olympiapark in Munich is a great example of such customizing and its benefit on even quite repetitive concrete structures.

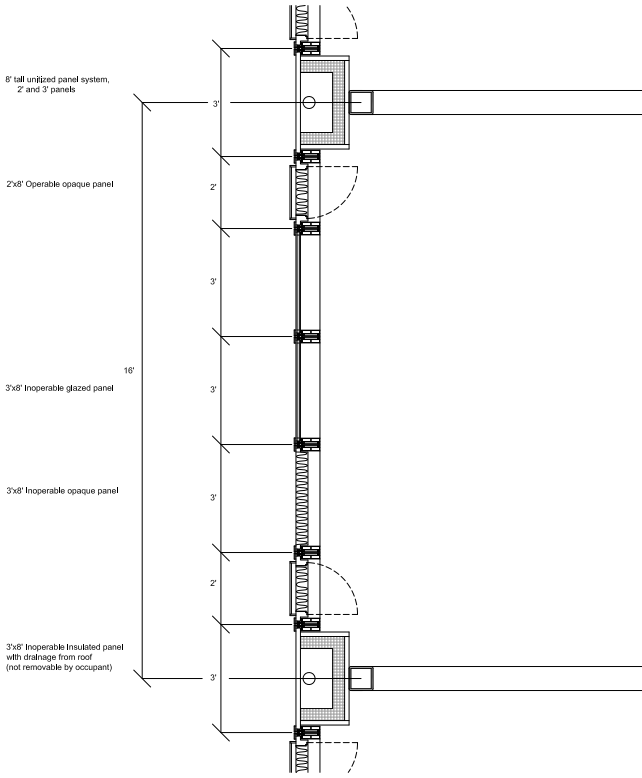


Facade Detail Section (left)

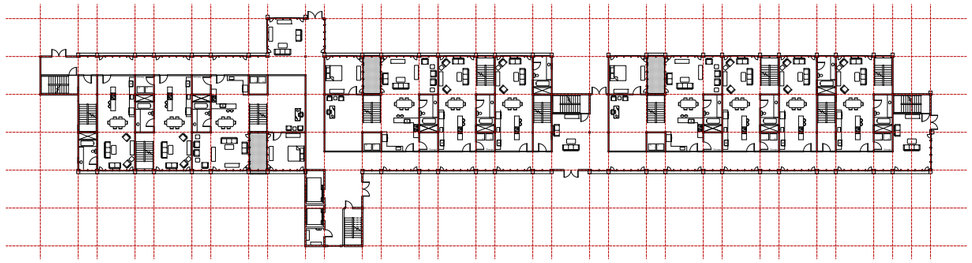
3/16” = 1’-0”

Facade Detail Plan (below)

3/16” = 1’-0”

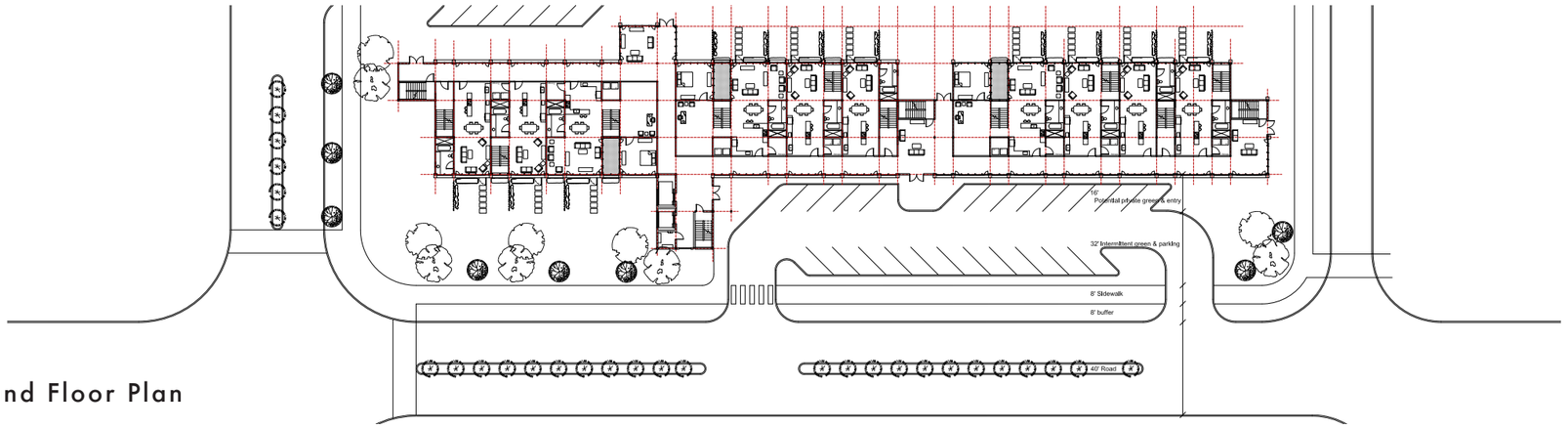


14 Building Scale Layout



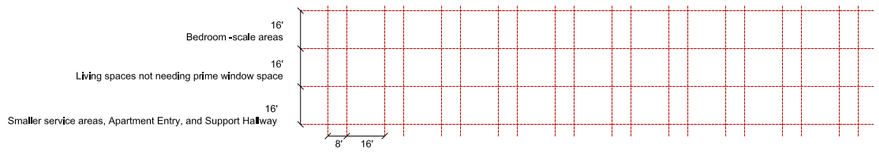
Typical Floor Plan

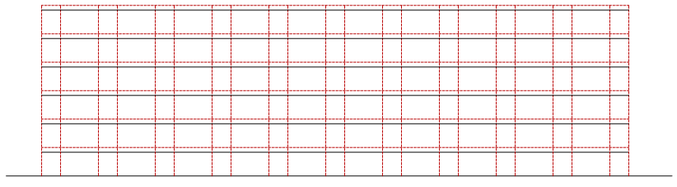
1/64” = 1’-0”



Ground Floor Plan

1/64” = 1’-0”





Structural Rhythm

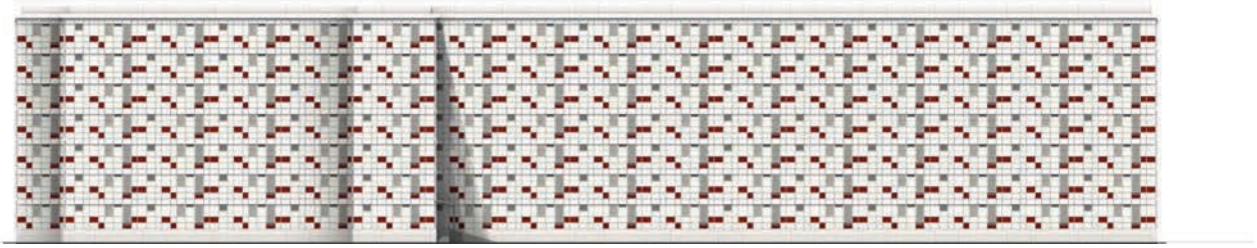
1/64” = 1’-0”

Long Building Section

1/64” = 1’-0”

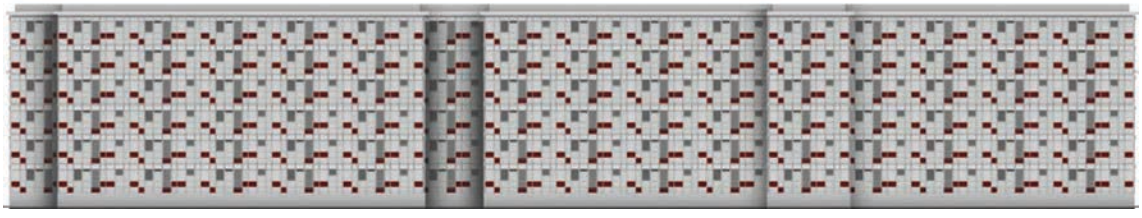
Short Building Section

1/64” = 1’-0”



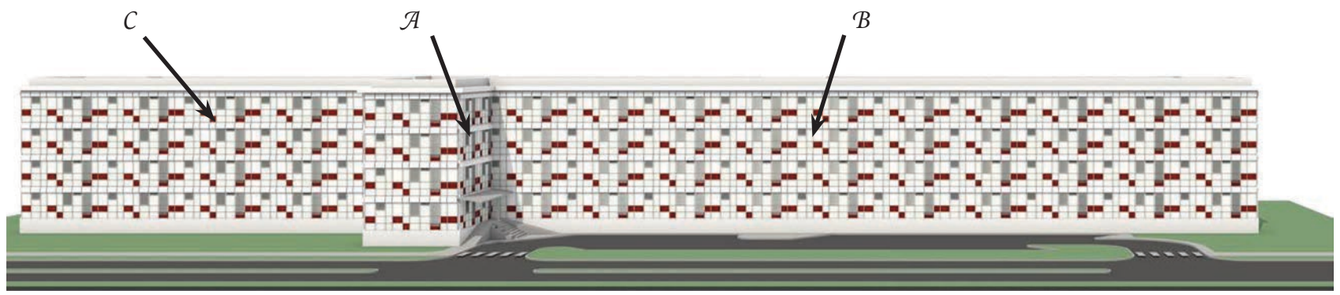
Long Building Elevation - East

1/64” = 1’-0”



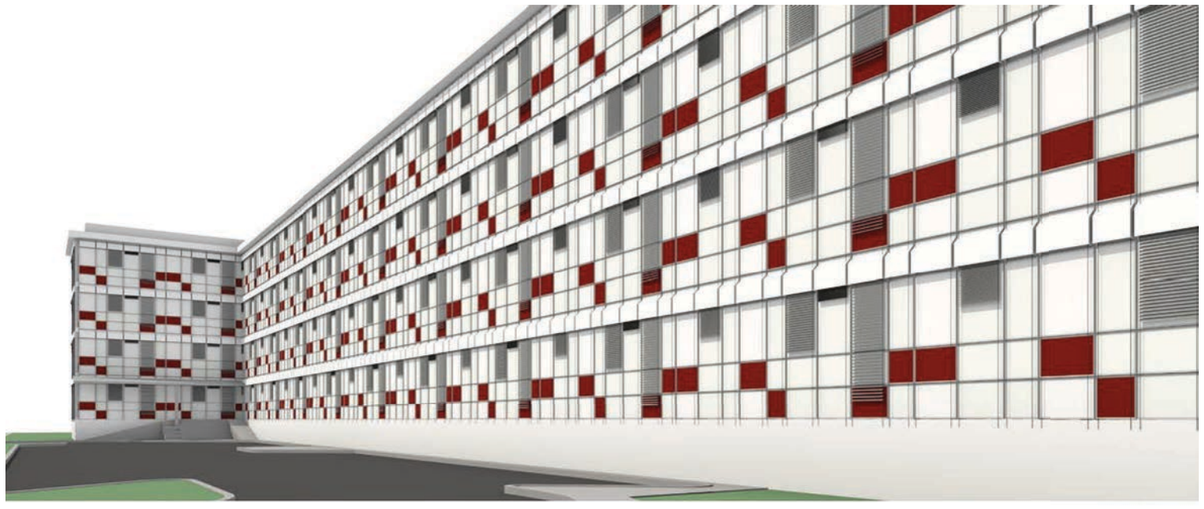
Long Building Elevation - North

1/64” = 1’-0”



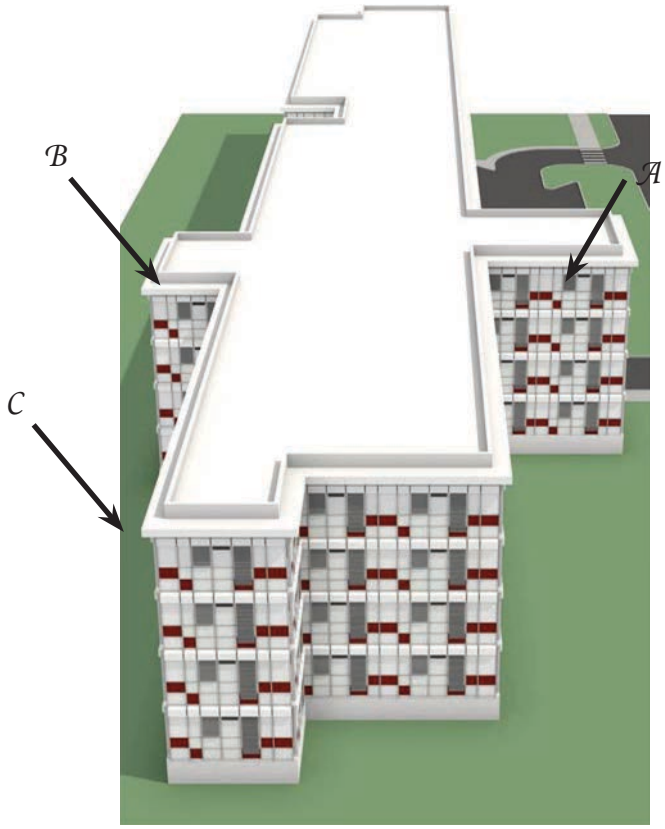
Long Building Perspective

Showing entrance and vertical core (A) Hallway-side Facade (B) and Unit-Side Facade (C).



Entrance Perspective

Showing entrance and Hallway-side facades from parking entry.



Building Perspective

Showing vertical circulation core (A), shared public space (interior, B) and shared open spaces (C).

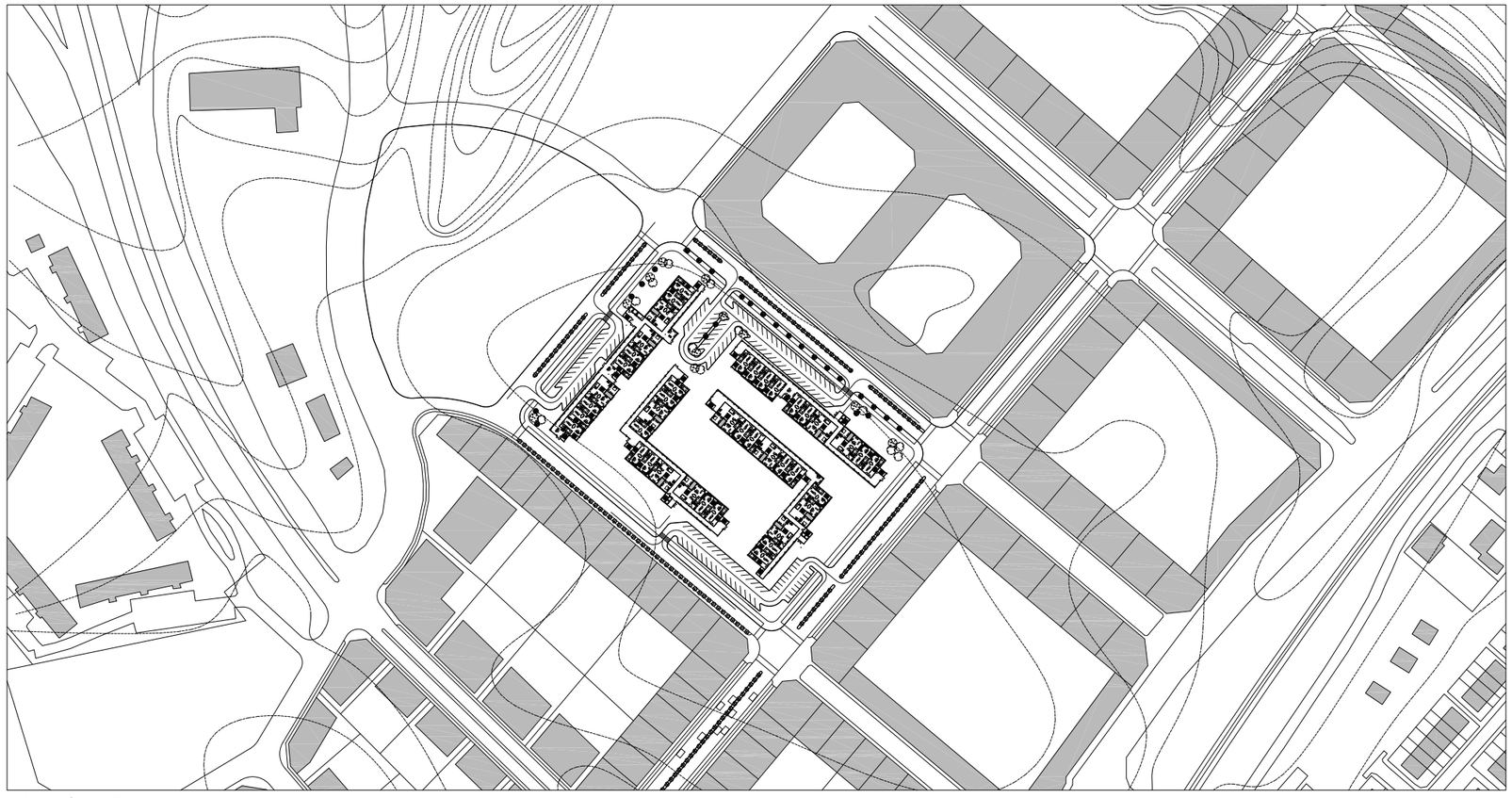
15 Site Scale Layout

The organization of the site massing is set up so that each apartment overlooks a green space on its main living level. The open spaces outdoors are arranged to provide a variety of scales for public shared activities, be it walking paths or a soccer field.

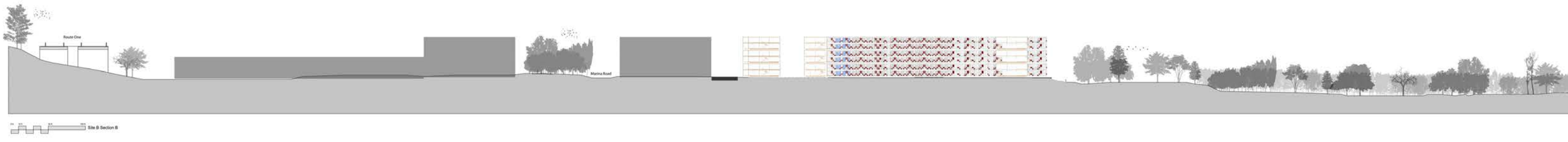
The structural rhythm of the buildings is consistent - as you can see from the red lines on the facing page - each line of columns creates a datum which can be used to structure the composition of exterior spaces.

Another Rule for the organization of the structures is that living unit's primary orientation should not be towards other living units or parking lots, they should always face a 32' wide green space first. (This is based on shadows a six story building in the summer and winter)

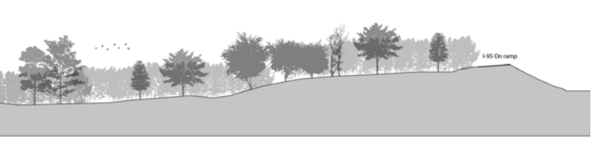
This system could be adaptable for other site contexts or organizations. The buildings structure and other rules are designed to allow a maximum of six stories, but the structure could remain skip-stop with the current units in varieties of 2 and 4 stories. Alternately, new units could be arranged with the same panel modules to allow for 3 and 5 storied buildings.



Massing Plan 1/64" = 1'-0"



Landscale & Ground Plan 1/32" = 1'-0"



Site B Section A

16 Annotated Bibliography

Davies, Colin. The prefabricated home. Reaktion Books, London, 2005.

The idea of the prefabricated home, while very different from my thesis, involves similar concepts such as the creation of somewhat modular pieces which are assembled to form the whole, and can usually be disassembled as well.

Gausa, Manuel and Salazar, Jaime. Housing/Single-Family Housing. Birkhäuser, Basel, 2002.

Includes precedents for single family housing and the topics of prefabricated housing and low-energy building, which involve similar concepts to my thesis.

Joshi, VK. "Lasting Architecture," Boloji Journal Online, September 28, 2008. Accessed September 10, 2010. http://www.boloji.com/environment/202.htm

This journal article talks about a series of multistoried houses built in the Himalayas that are earthquake resistant. It was relevant to me because I was looking for examples of architecture that has lasted through the ages, and what affect the longevity had on it's social impact. IE, was it used for the same reasons, etc.

LaBarre, Suzanne. "Life on the Edge". Popular Science. October 2010. Pages 44-57.

Also online: <http://www.popsci.com/environment/article/2010-09/life-edge>

Talks about modular passive solar systems and new strategies for technological integration.

Leger Wanaselja Architects, http://www.lwarc.com

Many of the works of these architects are relevant to my thesis because they reuse materials directly without re processing.

McDonough, William and Braungart, Michael. Cradle to Cradle. North Point Press, New York 2002.

This book is interesting in that it suggests guiding principles for the idea of recycling and reuse. One such founding idea is "waste equals food", which emphasizes the need for byproducts to be usable in some way, rather than filling land fills.

"Mobile Exhibition Pavilion". Detail Magazine. 2010 Issue 11, p1186.

Provides in-depth detail for precedent information.

"Residential Development in Chantepie". Detail Magazine. 2010 Issue 11, p1190.

In depth information on precedent.

Sadler, Simon, The University of California, Davis. “Drop City Revisited”. Journal of Architectural Education, ACSA 2006. pp. 5-14

Drop City was an interesting community which provides a look at what people can do with reclaimed materials.

Santini, Claudio. Green is beautiful: The Eco-friendly house. Images Publishing, Australia, 2009

A complete look at ecologically conscious design techniques, including the topics of Daylighing, Insulation, Existing Buildings, Passive Shading, Radiant Heating, Recycled Materials, Responsible Siting and Passive Solar.

Wilhide, Elizabeth. Eco: An Essential Sourcebook for Environmentally Friendly Design and Decoration. Rizzoli, New York, 2006.

A great outline of sustainable materials for all levels of design, structure, insulation and finish materials.

Yeang, Ken. Ecodesign: A manual for ecological design. Wiley-Academy, London, 2006.

A great guide on how to implement a building as an ecosystem. While not directly related to my thesis, this is relevant to the intent behind my thesis.